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ABSTRACT

A major focus in all areas of education today is the impact of education on students' ability to use higher order thinking skills. Understanding and improving the knowledge, cognitive abilities, and dispositions that guide, organize, and form effective action in the workplace, home, and community are significant problems for vocational education. This document provides an overview of educational and learning problems and reviews theory and research findings concerning the mechanisms by which people take in, process, store, combine, retrieve, and use information in directing, performing, and controlling operations, understanding and affecting situations, interpreting experience, identifying and solving problems, and making decisions and judgments. An agenda for inquiry is presented that reflects existing knowledge about higher order thinking, identifies potential ways of determining how and to what extent vocational education involves the application of higher order thinking skills, and leads to development of curricular and instructional models in vocational education that incorporate and develop higher order thinking. The inquiry agenda is divided into three interrelated parts. Part I concerns identifying and organizing problems and contexts central in vocational education. Part II concerns descriptions, documentation, and understanding of the knowledge, cognitive abilities, and dispositions required by the problems and contexts identified in Part I. Part III focuses on identifying, developing, and assessing curricular designs and instructional processes that facilitate development of the required knowledge, cognitive abilities, and dispositions. An outline of the inquiry agenda and 14 pages of references are provided in the appendix. (KC)

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Vocational Education and Higher Order Thinking Skills:

An Agenda for Inquiry

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VOCATIONAL EDUCATION AND HIGHER ORDER THINKING SKILLS: AN AGENDA FOR INQUIRY

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1986

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Executive Summary

It has long been recognized that knowledge of subject matter alone is an insufficient prerequisite for competent human functioning. Recent work in cognitive psychology, briefly reviewed in this document, has added much to what is known about human intellectual processes and their development. This new and rapidly developing knowledge base has far-reaching implications for educational practice and provides a basis for research concerning the role of vocational education in the development of higher order thinking processes.

A major focus in all areas of education today is the impact of education on students' ability to use higher order thinking skills. The importance of cognitive functioning to competence in the work place, home and community is increasingly recognized. Studies indicate that basic cognitive skills and abilities are directly related to job performance (Ghiselli, 1973; Hunter, 1980; Hunter & Hunter, 1982; Pearlman, Schmidt, & Hunter, 1980; Schmidt & Hunter, 1981) and may account for as much as one third of productivity differences between workers (National Academy of Sciences, 1984). Understanding and improving the knowledge, cognitive abilities and dispositions that guide, organize and form effective action in the work place, home and community is a significant problem for vocational education.

This document provides an overview of educational and learning problems, and theory and research findings concerning the mechanisms by which people take in, process, store, combine, retrieve, and use information in directing, performing, and controlling operations, understanding and affecting situations, interpreting experience, identifying and solving problems, and making decisions and judgments. An agenda for inquiry is presented that reflects existing knowledge about higher order thinking, identifies potential ways of answering the question, how and to what extent does vocational education involve the application of higher order thinking skills, and leads to development of curricular and instructional models in vocational education that incorporate and develop higher order thinking.

The inquiry agenda is divided into three interrelated parts. Part I concerns identifying and organizing problems and contexts central in vocational education and their requirements. Part II concerns description, documentation and understanding of the knowledge, cognitive abilities and dispositions the problems and contexts identified in Part I require. Part III focuses on identifying, developing and assessing curricular designs and instructional processes that facilitate development of the required knowledge, cognitive abilities and dispositions.

Suggestions for Readers

The chapters in this report are arranged so that readers can focus on sections most relevant to their interests. The first two chapters, which deal with educational and learning problems and definitions of thinking skills, are likely to be of interest to most readers. Educational administrators and policy makers will find in Chapter One discussions of reasons why thinking skills is becoming a central focus in education. Teachers will recognize familiar problems that are part of their everyday professional experience. Researchers will find in chapter one an identification of educational and learning problems and a discussion of their significance.

Chapter Two presents alternative definitions of selected broad concepts that are relevant to thinking and discusses their similarities, differences and limitations.

Chapter Three, which deals with theories concerning human intellectual processes, will be of interest to those who wish to delve deeper into the processes of thinking and their development and become familiar with findings about these processes which have been produced over the last fifteen years. Researchers will find a review of research literature from which researchable questions and problems might be generated. Teachers may also find this chapter of interest in understanding phenomena they experience every day and in identifying concepts that might be applied as they design and implement instruction.

Chapter Four outlines a program of research, identifying three major questions, and proposing inquiries to address them. This chapter will be of interest to researchers and to those policy makers who have responsibility for and are concerned with educational research. In addition, graduate students will find in chapter four, ideas concerning potential directions for dissertation and thesis research.

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CHAPTER I: INTRODUCTION

The purposes of this paper are to: 1) examine current knowledge about descriptions, acquisition, and demonstration of higher order thinking skills, and 2) outline an agenda for inquiry concerning the role of vocational education in developing thinking skills and the relation of thinking skills to a range of outcomes sought in vocational education. Specific objectives are to:

a. Summarize existing knowledge about higher order thinking skills.

b. Identify potential ways of answering the question, how and to what extent does vocational education involve the application of higher order thinking skills.

c. Identify a program of research leading to curricular and instructional models that explicitly incorporate higher order thinking skills into vocational education.

Desired outcomes of this document and the research that it is intended to generate are seen as focusing the attention of vocational educators on the thinking process aspects of their educational goals and tasks, increasing the knowledge base of vocational educators and other educators regarding higher order thinking skills, and increasing the effectiveness of vocational education in reaching its aims, and society's goals.

The procedures used to develop this report included: 1) a review of selected aspects of cognitive psychology theory and research literature, 2) consultation with other educational researchers, educational psychologists, educational administrators and managers, teachers from vocational and other subject areas, policy makers, State Board for Vocational Education staff, Minnesota Department of Education staff, Minnesota Vocational Education Research Committee representatives, and University faculty; 3) examination of educational materials designed to teach thinking and try out of instructional and assessment approaches concerned with thinking and problem solving in vocational education.

The result of these procedures is a program of research, which is presented in Chapter IV. Three major questions concerning vocational education and higher order thinking skills are identified along with suggested research to address them. The intent of this document is to encourage research that will build a cumulative and interrelated knowledge base about vocational education and thinking processes.

Rationale

It has long been recognized that knowledge of subject matter alone is an insufficient prerequisite for competent human functioning. Recent work in cognitive psychology has added much to what is known about human intellectual processes and their development. The cognitive psychology theory and research briefly reviewed in this report have far-reaching implications for educational practice, and provide a basis for research concerning the links between knowing, doing and thinking and the role of vocational education in their development.

In a recent published interview, Robert Sternberg, a Yale cognitive psychologist, states a rationale for the emphasis on and interest in thinking skills in education today:

> If one takes the view that the major purpose of (education) is to help students become good problem solvers and to recognize what problems are worth solving, to become good decision makers and to know when decisions need to be made in the first place - if we want students to improve and make the most of the abilities they have, then we really don't have any other alternative. Bodies of knowledge are important, of course, but they often become outdated. Thinking skills never become outdated (Quinby,1985, p. 53).

A major focus in all areas of education today is the impact of education on students' ability to use higher order thinking skills. An impetus for this focus is the emergence of an information society in which peoples' daily lives and work increasingly demand their ability to process large amounts of information in systematic ways. Forces driving this demand include the rapidly increasing amount of available knowledge and information and its complexity. The widespread utilization and integration of computers throughout the society reflect this increasing demand for information processing capability.

Understanding and documentation of the intellectual processes involved in vocational education is a significant problem for vocational education as the importance of cognitive functioning to competence in the work place, home and community is increasingly recognized. For example, studies have indicated that basic cognitive skills and abilities are directly related to job performance (Ghiselli, 1973; Hunter, 1980; Hunter & Hunter, 1982; Pearlman, Schmidt, & Hunter, 1980; Schmidt & Hunter, 1981) and may account for as much as one third of the productivity differences between workers (National Academy of Sciences, 1984).

The significance of thinking skills has been recognized by the vocational education community in Minnesota as evidenced by its stated priority on "identification and experimentation with models that incorporate basic skills, higher order thinking skills and job-seeking/maintenance skills into vocational education," (Minnesota Research and Development Review Committee for Vocational Education, 1985). The application of new findings in cognitive psychology, to vocational education has been of interest to the national vocational education community as evidenced by the recent commissioning of a paper on this topic. (Laster, 1985).

If vocational education is to be improved as a result of the burgeoning research findings concerning thinking skills and their development, vocational educators will need to become involved in research efforts that explore application of these new findings to vocational education. In addition to enhancing the significance and effectiveness of vocational education, such research has the potential to add to more general understanding of thinking and learning processes to the extent that vocational education addresses unique aspects of these processes.

Enduring Educational Problems

Educators and educational researchers have worked for many years to try to understand and solve certain educational problems that have persistently resisted solution. These interrelated problems have been experienced in all areas of education and progress in their solution would be a major contribution to the field of education generally.

1. The Problem of Inert Knowledge

It is frequently documented via tests and other types of observations of learners that teaching results in learning of new terminology. It is often assumed that when learners use new terminology they understand and can use the concepts represented by the terms they appear to know. Yet, when students are presented with a problem or situation that they might be typically expected to face in their work, home, or community, they do not seem to connect the problem with what they know that would be relevant. It might be said that the student "knows" but that what they know is "inert" or has no power of action. Consequently, the impact of stored knowledge on learners' ability to deal with various problems and situations they encounter may be minimal. The challenge for educators is to design education in such a way that the knowledge students learn can be activated and accessed when it is relevant.

2. The Problem of Transfer of Learning

The ability to appropriately transfer the essence of what is learned from one situation to another is critical if education is to attain some level of efficiency. If learning cannot be transferred from one situation to the next, it remains inert for all but the context(s) or situation(s) in which it was learned and students must learn concepts and principles in relation to each problem and situation in which they must apply them. Such a task is ever more impossible as the quantity of knowledge increases and as problems become more complex in nature. Yet, studies of transfer of learning have not been very promising concerning its possibilities, at least as an implicit by-product of instruction.

3. The Problem of Integration of Knowledge

It is frequently observed that learners can repeat facts as they have been memorized but when t[illegible] are asked to relate one fact to another or facts to principles, or prin[illegible] to needed action, they are unable to do so. Their knowledge appears t[illegible] series of discrete units, seldom interconnecting to form a whole more powerful structure useful for confronting the real life work, home and community problems the learner faces.

4. The Problem of Going Beyond the Given

This problem concerns students' ability to push beyond what is given and be alert to aspects of situations that are not pointed out but are important in accurately and adequately interpreting the situation and in choosing and implementing action for the situation. Inference processes are a central component in such activity. For example, factors that are critical in causing a problem in the real world and solving it are often not specified. Individuals must be able to use their intellect to go beyond what is explicitly given and identify the factors from cues they are able to notice in the situation.

This problem is reflected in observations indicating that, although learners quite readily learn labels and terms and might be able to recognize an instance of a concept or a category, they seem far less able to understand what the instances mean in relation to a particular problem, situation, or event and, as a result, are unable to determine their significance or what might happen or what action would be appropriate to take. Because the significance and meaning of factors in a situation or problem are usually not "given" in real world problems and situations, the problem solver must know or determine them in order to develop effective and appropriate action.

Like transfer of learning, the ability to interpret phenomena is not likely to be an implicit by-product of educational experience, particularly if the experience simply focuses on learning of terms and sequential procedures without demanding interpretation from students as part of the learning process.

5. The Problem of Identifying and Understanding Different Types of Problems

In education there have been few attempts to identify different kinds of problems, the essential features and dimensions along which they vary, and the implications of that variation for defining them and identifying approaches to solving them. For example, one study in the field of medicine suggests that people may approach system failure or trouble-shooting problems deductively by establishing a series of hypotheses and then proving or disproving each in trying to locate the trouble spot (Elstein, Shulman, and Sprafka, 1978). Knowledge about problem types, their critical dimensions, and approaches for solving each type would be a very helpful basis for teaching students recognition of and ways of defining and solving different types of problems.

Summary

In summary, these five problems suggest that when knowledge is not integrated into a network of relationships, it is likely to remain inert and is unlikely to transfer across situations. If learners cannot push beyond the given, beyond what is immediately apparent and explicitly pointed out, they are unlikely to be aware of and appreciate the significance and meaning and consider the implications of experiences and events. If learners have no sense of problem types within which to sort and categorize problems they encounter, they will have a less powerful basis for transfering problem recognition, definition and solution strategies across problems and situations.

The five problems relate to learners' ability to be conscious about the processes and approaches they use in taking in new information, organizing it, and bringing it to bear on their experience. The term applied in cognitive psychology literature to this consciousness of one's own intellectual functioning is meta cognition. One general approach that has been identified as a way of addressing these five problem areas in instruction is to help students be more conscious of their own intellectual functioning. In order to do that, educators need to understand that functioning. This document and the research it outlines addresses the need for this understanding and its application in vocational education.

CHAPTER II: DEFINITIONS AND CONCEPTS

This chapter reviews definitions of terms and concepts associated with thinking. Four broad umbrella terms are discussed: higher order thinking, intelligence, competence, and creativity. The discussion of higher order thinking is followed by a discussion of more specific thinking and intellectual processes often associated with the term, higher order thinking, and which have been identified as requiring complex and sophisticated mental processing. These include: problem solving, critical thinking, and practical reasoning. Comprehension is also discussed as a foundation for these more complex processes.

Not all current definitions and conceptualizations of thinking skills are equally grounded in research evidence or reach a level of depth and precision that is necessary to be able to successfully incorporate them in instructional design or document that learners have developed them. Further, much of the research literature on thinking is more in a theory development stage than a theory application stage, although application level work has increased dramatically in the last five years. The applied work that has been done is primarily focused on math, science, and reading. Very little work has been done that links the body of knowledge on thinking to vocational education, although some work focusing on thinking skills and technical education is beginning to emerge.

The basis for selection of the thinking and intellectual processes discussed in this chapter include the degree to which research has developed to a point of providing precise concepts and a basis for instruction (this is most characteristic of comprehension and problem solving), the degree to which the processes are central in and significant to outcomes sought by one or more areas of vocational education, and the degree to which the processes have been identified as needed for functioning in life and work situations of the future.

Higher Order Thinking

The meaning of the term, higher order thinking skills, is in a state of flux. The term is criticized because it is often used as a catch-all term to mean whatever the speaker or writer intends and, when used in this way, lacks precise or agreed upon meaning. Despite this problem, and no doubt because of it, progress is being made in clarifying what is meant by higher order thinking skills. For example, Sternberg indicates that, to a surprising extent, people are saying the same thing using different words (Quinby,1985).

Higher order thinking refers to the more complex levels of intellectual functioning. Frequently, the upper four levels in Bloom's (1956) cognitive domain taxonomy (i.e., application, analysis, synthesis, evaluation) are identified as higher order thinking, although Duck (1985) includes the upper five levels, which adds comprehension. Higher order thinking is viewed as involving those mental processes that demand more than the simple encoding and storing of information in memorization and simple recognition of examples of concepts.

Another type of definition was provided by Janet Laster (1985) in her review of the cognitive science literature with respect to its implications for vocational education curriculum. She defined higher order thinking as purposefully processing information beyond superficially memorizing or recalling information. Sam Messick (1984) provided a similarly general definition: any cognitive mode of developing connections or anticipating outcomes.

A more elaborated definition of higher order thinking is provided by Quellmalz (1985): "Students engage in purposeful, extended lines of thought during which they: 1) Identify the task or problem type; 2) Define and clarify essential elements and terms; 3) Judge and connect relevant information; 4) Evaluate the adequacy of information and procedures for drawing conclusions and/or solving problems. In addition, students engage in meta cognition. This involves becoming critical of the strategies they use, becoming self-conscious about their thinking, and developing self-monitoring, problem solving strategies." According to Quellmalz, commonly specified higher-order reasoning processes are the cognitive processes of analyzing, comparing, inferring and interpreting, and evaluating, and the metacognitive processes of planning, monitoring, and reviewing and revising. Quellmalz describes his definition as an attempt to merge a goal-directed, problem solving perspective with an inferential, evaluative, critical thinking perspective. Both of these perspectives are reflected in this chapter. The next chapter further elaborates the problem solving perspective.

Sternberg (Quinby,1985) identifies three processes associated with thinking. These are: 1) executive processes or metacomponents which include planning what you're doing, monitoring while you're doing it, and evaluating when it's done, i.e., metacognition. 2) performance processes which include actually doing what the executive processes tell you to do; and 3) knowledge-acquisition or learning components which involve learning how to do the problem solving.

Additional concepts of higher order thinking are provided by writers and organizations representing various school curricular areas in discussing the contributions of these curricular areas to the development of the intellectual processes being defined (Duke, 1984; Kurfman & Cassidy, 1977; National Council of Teachers of Mathematics, 1980; National Council of Teachers of English, 1982). Higher order thinking skills are defined by these groups as: logical reasoning, information processing, decision making, problem solving, how to think, analyzing, classifying, comparing, formulating hypotheses, making inferences, drawing conclusions, criticizing, interpreting, translating abstract concepts into tangible, visual, auditory or kinesthetic expressions, making and supporting discriminatory judgments, and drawing facts and inferences from contexts.

The following sections review definitions of more specific thinking processes often identified as higher order thinking.

Comprehension

Although not always included in definitions of "higher order thinking" comprehension is included here because it is an essential foundation from which the thinking processes more frequently identified as "higher order" operate. Further, there is some indication that comprehension takes place at several levels, organizing and reducing information at lower levels and symbolizing, or "representing" it at higher levels (Van Dijk, 1977). Comprehension is the process in which an individual constructs an internal representation of incoming information. Comprehension is concerned with interpretation of meaning of events, information and phenomena and, as such, heavily influences the direction of thought and action with respect to incoming information. Comprehension is central in such activities as extracting meaning from printed material, oral communication, visual observations, auditory input, and situational phenomena. It is involved in reading and understanding a technical manual, knowing what a child's cry means, interpreting a supervisor's tone of voice or an odd sound in an engine, etc.

Bloom (1956) identified three aspects of comprehension as translation, interpretation and extrapolation as a basis for educational objectives. Translation involves changing the form of information and ideas. Interpretation concerns separating the relevant from the irrelevant, the more essential from the less essential, and identifying interrelationships between parts. Extrapolation has to do with extending beyond what is given to what is implicit in or beyond the given information or situation. It involves recognizing a pattern and extending what is given beyond current parameters by applying the pattern.

Problem Solving

Problem solving comprises a major area of research in cognitive science. As a result, definitions and concepts associated with problem solving are more fully and precisely developed than is the case for some other higher order thinking processes.

Anderson (1980) defines problem solving as any goal directed sequence of cognitive operations. This definition points to a number of characteristics typically embodied in concepts and definitions of problem solving: 1) it is goal directed; 2) it involves a sequence of mental steps (i.e., it is not a single operation); and 3) the goal-directed activity depends significantly on cognitive operations. The process of problem solving involves identification of current and desired states, specification of goal(s), and finding a sequence of operations or operators that transform the initial state into a goal state in which the goal is satisfied.

Anderson (1980) distinguishes between creative and routine problem solving. Creative problem solving requires development of new procedures whereas routine problem solving uses existing procedures.

Elstein, Shulman & Sprafka (1978) define problem solving in their study of medical diagnosis as the process of making adequate decisions with inadequate information and as those forms of decision making that involve the processing of information to make judgments. Their definition emphasizes decision and judgment processes as a part of the problem solving process.

Critical Thinking

Dewey (1933) defined critical thinking as reflective thought; careful, persistent examination of an action, proposal, or belief, and the analysis or use of knowledge in light of grounds that justify it and its probable consequences. Smith (1953) defined critical thinking as the ability to determine what a statement means and whether to accept or reject it. Critical thinking is defined by Robert Ennis (1985) as reflective and reasonable thinking that is focused on what to believe or do. Ennis describes critical thinking as a practical activity, encompassing the practical side of higher order thinking. According to Ennis, critical thinking involves both dispositions and abilities. Dispositions have to do with an individuals' general stance toward information and experience and include such things as trying to be well informed, being open-minded, paying attention to the total situation, and seeking reasons. Abilities include being able to clarify issues and information, establish a sound basis for inferences, make inferences, and use decision making and problem solving processes in an orderly and systematic fashion.

The critical thinking aspect of higher order thinking has tended to have more attention from philosophers than psychologists and, consequently, empirical research on critical thinking is considerably more limited than that on problem solving.

Practical Reasoning

The relationship of critical thinking to practical reasoning is reflected in Ennis's definition of critical thinking presented in the previous section. Like critical thinking, most of the work on practical reasoning has come from philosophy rather than psychology and consequently little empirical research has focused on it. Practical reasoning involves the endorsement of a conclusion which commits an agent to action. It involves the values, wants or volitional attitudes of the agent and is a means of determining how states of affairs are to be altered by the intervention agent (Clarke, 1985). The focus of practical reasoning on states of affairs links it to problem solving. Its focus on evaluation based on value judgments links it to critical thinking. Critical thinking and practical reasoning differ from problem solving as defined in most of the psychological literature in that problem solving concerns judgments of fact whereas critical thinking and practical reasoning involve both judgments of fact and judgments of value.

Intelligence

Recent concepts of intelligence have increasingly expanded beyond the idea that intelligence is "bestowed," stable and static to the idea that intelligence has multiple dimensions that are learnable to at least some extent through experience and education. Perkins (1986) identifies three ways of thinking about intelligence that reflect these shifts. A power view of intelligence characterizes it as more or less "bestowed" and relatively stable, unchanged to any large extent by learning. A tactical view of intelligence focuses on strategies for using the mind in such tasks as memorizing and solving problems and contends that such intelligence can, at least to a certain extent, be taught. The third view of intelligence as content emphasizes the knowledge base in a particular domain of knowledge. Mastery of domain-specific content and skills signifies intelligence in this view. Earlier concepts of intelligence factors or abilities represented by the terms, fluid and crystallized abilities, are incorporated in the newer views. Fluid abilities include skill in assimilating new information and solving new problems. Crystallized abilities include knowledge possessed as a result of experience and education (Gardner, 1983; Sternberg, 1985).

Two researchers who have contributed to the more recent vision of intelligence are Sternberg and Gardner. According to Sternberg (Quinby, 1985), intelligence needs to be conceptualized as a multidimensional profile of strengths and weaknesses. Sternberg points out that concepts of intelligence also need to incorporate context. Intelligence includes thinking skills but also involves learning and perceptual skills. Further, Sternberg contends that concepts of intelligence should not be limited to simply the possession of abilities and skills but should also include the use and transfer of thinking skills. Sternberg identifies three components of intelligence: thinking, dealing with novelty, and contextual intelligence. Thinking involves executive processes (metacognitive skills), performance processes, and learning processes that result in knowledge acquisition. These three components of thinking were defined in the section of this chapter concerning higher order thinking. Dealing with novelty, also termed synthetic or creative thinking by Sternberg, involves going beyond given information and coming up with one's own ideas, and seeing new problems in old ways or old problems in new ways. Contextual intelligence, also termed social or practical intelligence by Sternberg, involves the ability to transfer abstractions to the real world and to succeed in everyday life. This component of intelligence depends on tacit (implied) or informal knowledge, knowledge that is almost never explicitly taught but yet is needed in order to succeed in the various situations of life.

Recent research by Gardner (1983) has lead to his identifying intelligence as a much broader phenomena than that typically associated with academic success. Gardner identifies and partially validates six relatively autonomous forms of intelligence possessed by humans. These are linguistic intelligence, musical intelligence, logical/mathematical intelligence, spatial intelligence, kinesthetic/bodily intelligence, and personal intelligence. Linguistic intelligence is the ability to communicate, explain, and coerce with language. Musical intelligence is the ability to create or perform music. Logical/mathematical intelligence is the ability to order and reorder objects, assess quantities, and perform calculations. Spatial ability is the ability to perceive visual phenomena accurately, intellectually perform transformations and modifications of visual phenomenon, and to recreate images without physical referent present. Bodily/kinesthetic intelligence is the ability to use one's body in highly varied and skilled ways for expressive as well as directed purposes. Personal intelligence is the intelligence of feelings, including the capacity to assess one's own feelings in particular situations and to notice and make distinctions among the feelings of other people with respect to mood, temperament, motivations and intentions.

Competence

Competence is a term with many different meanings (Pottinger & Goldsmith, 1979; Raven, 1984; Short, 1984). Broad complexes of integrated skills and abilities rather than isolated components or tasks are increasingly the focus of educational aims and of human and societal needs predicted by futurists. Competence is a concept that encompasses such breadth and integration (Pottinger & Goldsmith, 1979).

Lachman, Lachman and Butterfield (1979, p. 77) define competence as the knowledge that people carry around in their head and use to produce and understand actions and phenomena. Messick (1984, p. 1-6) defines competence as what an individual knows and can do in a subject area however that knowledge or skill is acquired. He describes competence as a continuous variable, and distinguishes it from a standard of adequate or sufficient performance. Other useful discussions of competence in relation to continua and standards are provided in Pearson (1984) and Klemp (1979). Messick underscores the integration of complex skills by describing competence as characterized by complex, highly developed knowledge and ability structures integrating in complex ways. Lachman, Lachman and Butterfield (1979) point out the centrality of patterns in knowledge for competence. Patterns are rules which guide behavior. Others' discussions of competence have also noted the importance of patterns and indicated that it is patterns rather than a summation of isolated skills that makes up competence (Pottinger, 1979).

The intellectual, thinking-oriented aspects of competence are emphasized in a statement by Klemp (1977): "...it is not the acquisition of knowledge or even the use of knowledge that distinguishes the outstanding performer, but rather the cognitive skills that are exercised and developed in the process of knowledge acquisition and use that constitute occupational competence. In other words, the information processing skills related to learning, recall, and forgetting are not so important to success as the conceptual skills that enable one to bring order to information chaos that characterizes one's everyday environment..." (p. 2). Such cognitive skills are elaborated by McGuire in research on professional practice into a seven-level continuum based on complexity and multidimensionality: recall of isolated information, recognition of meaning or implication of performance, simple interpretation of data or application of a single principle or standard, combination of principles, analysis of data or application of a unique combination of principles to a novel problem, evaluation of a total situation, and analysis of a variety of elements of knowledge and application to a novel problem situation in its entirety (Loveland, 1976).

Competence is further defined as "the ability to generate and coordinate flexible, adaptive responses to demands and to generate and capitalize on opportunities in the environment (Waters & Sroufe, 1983, p. 80). Other definitions of competence include skills, and ability to see possibilities and to choose among them (Bronson, 1984; Wolf, 1984).

The environment, or setting, has been identified as a mediator of performance (in occupational settings, for example) in relation to variation in working climate and demands that are independent of a person's skills, personal characteristics and the job requirements (Pottinger, 1979).

Raven's (1984) work on competence has revealed the significance of motivation, values, perceptions, priorities and expectations in contrast to abilities alone as essential in competence. White (1959) also linked motivation to competence. Such elements will be referred to in this document as dispositions.

Creativity

Although creativity has been studied for decades, it is a phenomenon about which there is much that remains unknown. One aspect of creativity that has value across subject fields and problems is insight. For example, insight is one approach identified by Wickelgren (1974) to solving problems. Perkins (1986) identifies insight as a central element in creativity. Insight appears to be the product of mental processes similar to other kinds of thinking. Further, Perkins contends that creativity involves critique, and therefore, is related to critical thinking. He defines creativity as a style closely linked to personality, as opposed to an ability.

Creative people use their abilities in certain ways which are intentional and volitional (Perkins, 1986). They attend differently to situations from less creative people and are more problem-finding oriented than solution oriented in their approach to problem solving. Some characteristics of creative people that have been identified include preference for complexity over simplicity and change over routine, independence in judgment, interest in meanings and implications rather than concrete detail, refreshed rather than tired by their work, flexible rather than rigid, and intuitive rather than sense perception in orientation (MacKinnon, 1960, 1967, Barron, 1953a, 1953b, 1968, 1969). Although often used as an indicator of creativity, Perkins (1986) contends that fluency of ideas does not necessarily signal creativity.

Perkins identifies products with creativity and particularly focuses on design as the product of inventive thinking and as a creative product. Design is a broad term which would apply to the design for a building, the design of an environment for a child, the design of a plan of action, the design of an inventory system, etc. Jackson and Messick (1965) identify four characteristics of creative products:

1. Appropriateness given the situation and the desires of its producer(s).
2. Novelty, which means uncommon, remote, clever.
3. Transformation, which occurs when people's perceptions of their world are altered and barriers are overcome.
4. Condensation, which is the power of a creative product to continually yield new and exciting revelations upon repeated examinations.

Summary

Concepts of higher order thinking, intelligence, competence, and creativity defined and discussed in this chapter all represent significant areas of knowledge in educational, psychological and philosophical literature. However, the extent and nature of research that focuses on the mechanisms by which each of these concepts and processes are engaged, developed and operates differs widely. Further, the research that has focused on some of the processes is more directly applicable to instruction than is research and theory focused on other processes. Consequently, the research and theory presented in next chapter focuses on information processing and problem solving, two areas where research has concentrated on underlying mechanisms and which offer promising applications for instruction. The intellectual processes included in Chapter II that will be most reflected in chapter III are comprehension and problem solving. However, all of the processes will be incorporated to some extent in the inquiry agenda presented in Chapter IV.

Chapter III: Theory and Research

Several major groups of theories and research, largely within the cognitive science component of psychology, have undergone rapid development within the last fifteen years and are at a point where they are beginning to provide a useful foundation for instructional and curricular development, and assessment of student learning. These developments allow more precise definitions and concepts of thinking, more focused teaching of intellectual processes required in order to use knowledge, better structured curriculum that will result in better retained and more usable learning, and more comprehensive assessment that goes beyond rote memory and recall levels of intellectual functioning. Some of these groups of theories and research include information processing, human problem solving, artificial intelligence, and systems theory. These bodies of theory and research are increasingly addressing the mechanisms by which information enters, is stored, represented and processed in the cognitive structure, the conditions which surround these mechanisms, and differences among individuals in executing such mechanisms. Such mechanisms and their consequences determine the manner in which problems are solved, how individuals focus their attention on and ascribe priority and value to phenomena, ideas and events, and the ways in which individuals determine their actions.

This chapter briefly reviews two groups of cognitive science theory and research: information processing and human problem solving. Human problem solving research frequently incorporates artificial intelligence as an approach to understanding human intellectual functioning.

Cognitive psychology represents a major conceptual shift from the behaviorist tradition in psychology which has predominated in educational thinking and designs in the past. The "black box" metaphor (see Fig. 1) illustrates this shift. The black box represents the human mind. Behaviorist psychology assumed that, since the black box could not be opened to observe its operation, focusing attention on it was not fruitful. To focus on what was observable, i.e., inputs to and outputs from the black box, was believed to be a more useful approach. Given this perspective, it is not surprising that instruction and assessment of student learning have focused more heavily on inputs to and products from mental processes rather than on the mental processes themselves.

In contrast, cognitive psychology, which has been credited with replacing behaviorism in the 1970's as the dominant psychological framework for understanding human functioning (Anderson, 1980), focuses directly on the structure and operation of black box. Cognitive psychology presumes and has demonstrated that it is possible to indirectly observe the processing occurring in the black box.

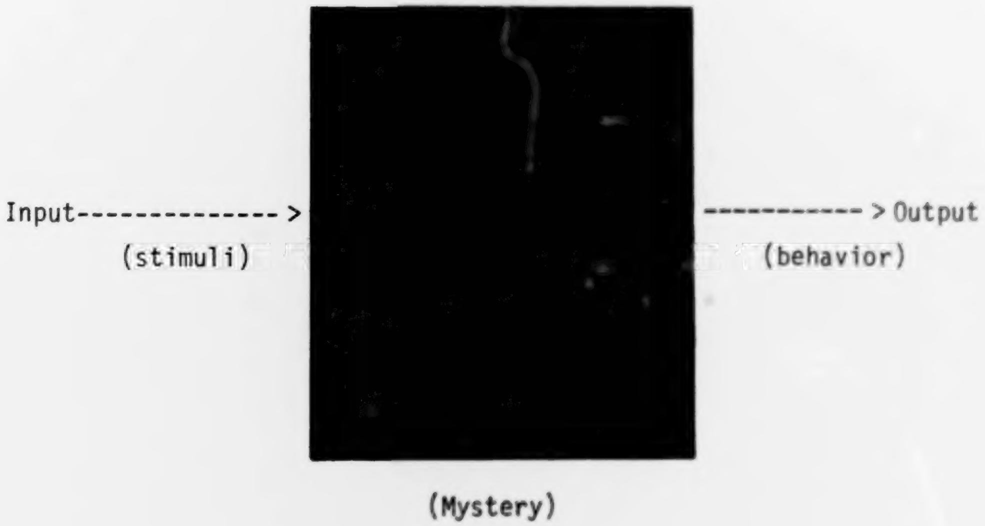

Figure 1. Black box metaphor.

Information Processing Theory and Research

The level of precision and increasingly extensive development of the knowledge base concerning human information processing make it a useful foundation for research and development in education.

Information processing theory is a branch of cognitive psychology concerned with the way humans collect, store, modify and interpret information from their environment, retrieve and restructure already stored information, and how people use their knowledge and information in every facet of human activity. Information processing theory considers everything that is known by a person as "represented" (i.e., symbolically organized and stored) in the person's memory (Lachman, Lachman & Butterfield, 1979). The ways knowledge is represented and coded for storage in the human memory and the internal processing mechanisms underlying behavior are concerns of information processing theory.

The potential significance of information processing theory and concepts to vocational education lies in its usefulness in: 1) explaining meaning and why the same situation, actions or events can have different meanings for different people; 2) the probable influence of representation on how an individual identifies, interprets and defines a problem situation; and 3) the potential of representation to facilitate or limit the generation of solutions for a problem.

Information processing research findings reveal several factors which influence the storage, coding, retrieval, structuring and application of knowledge by human beings. Some of these include (Lachman, Lachman & Butterfield, 1979; Anderson, 1980):

1. The importance of context

-The context in which something is learned is a factor in retrieval of that knowledge. Bits of knowledge appear to be encoded in the brain according to the learning context. Cues in the learning context are associated with the codes by which knowledge is stored. Codes appear to be internally constructed on the basis of the context in which the information was experienced and the person's already stored knowledge. Unfamiliar cues present in a new context may not activate the codes by which knowledge is stored even though the stored knowledge may be relevant to the new situation. Consequently, a person may possess stored knowledge relevant to a situation but be unable to recall the knowledge when in that situation. This may explain what many teachers have observed when students do well on the sample problems or the in-class examples experienced under teacher guidance but cannot apply what they obviously have learned to new problems in an assignment. This finding is relevant to the educational problem of inert knowledge and suggests a significant role for vocational education as providing a context that renders knowledge usable in work and life situations.

-Recall appears to be better when aspects of the encoding (learning) context are present at retrieval, but the entire encoding context need not be perfectly reproduced for retrieval to occur. Only a sufficient number of relevant aspects of the encoding situation need be present to facilitate recall. Students may differ on the number of relevant aspects of the encoding context that need to be present in order for retrieval to occur. This finding is relevant to the educational problems of inert knowledge and learning transfer.

-Because the means for retrieving knowledge is established at the time the knowledge is stored in the brain, transferability of learning across situations is not likely to occur automatically unless provision for such transfer is part of the learning process. Knowledge learned in a generic, context-free way may not transfer to a range of situations unless links between the different cues present in varied situations and the codes by which the knowledge is stored are explicitly established in the learning process. Further, knowledge that is only coded for a single context is also unlikely to transfer across widely varying situations.

-The learning context determines which aspects of a concept will be encoded. The mathematical aspects of hydraulic pressure learned in the context of a hypothetical physics problem may not necessarily be encoded in such a way that a learner can understand, evaluate, and appropriately operate on a malfunctioning hydraulic lift or robot.

2. Existence and development of different memory systems

-There is a debate in the literature as to whether visual, verbal and motor coding systems are separate memory systems or all part of one memory system. Other ways in which memory has been categorized in different systems include episodic memory (personal memories, autobiographical, one's own past including the context of experiences) and semantic memory (general knowledge, knowledge of words and symbols and their meanings and relationships, rules). Memory for perceptual events, which are most often visual, has been identified as analogical memory (Lachman, Lachman & Butterfield, 1979).

-Concepts may be stored separately from concept labels. Evidence used to support this premise is the frequently occurring phenomena of being able to recall a person but failing to remember his or her name. This finding is useful in understanding why a student may be able to correctly fill in the blank on a label- memorization focused test but fail at an item or in a situation that demands conceptual understanding.

3. Relationships between knowing and doing

-Declarative and procedural knowledge are central concepts in information processing theory and evidence suggests that they represent a learning continuum. Beginners start with the acquisition of a critical mass of facts, information, concepts and principles (i.e., declarative knowledge) whereas experts have transformed that declarative knowledge into procedural knowledge (i.e., skills one knows how to perform, knowing how one arrived at a particular conclusion and knowing what one did in performing a particular action or task) which they are able to use when appropriate and in effective ways (Anderson, 1980). Procedural knowledge incorporates the function of the stored knowledge. It also enables the individual to focus attention on those aspects of a situation (cues) which are relevant to acting upon it to achieve a desired goal. This finding helps to explain why traditional recall tests which tap only declarative knowledge provide little information about the degree to which a student can use that knowledge.

-Productions is the term applied to procedural knowledge. Productions enable a person to recognize when a given action will be useful. They are comprised of an action together with a condition or conditions specifying when the action is to be taken. Another term that is applied to this kind of knowledge is condition-action units. The condition portion of the unit contains the conditions under which a given action is appropriate; the action portion specifies the action that is appropriate under the specified conditions. Anderson (1980) claims that the concept of productions has replaced that of S-R bonds in understanding human functioning since 1970.

-People appear to be able to communicate (and may be more conscious of) their declarative knowledge than their procedural knowledge. According to Anderson (1980), once proceduralization has occurred, it may be almost impossible for a person to extract their declarative knowledge and separate it from the performance of the procedure.

-Strategic knowledge is the ability to set goals and subgoals and to form plans for attaining goals. It is a type of metaknowledge that allows one to monitor how one is doing and to make changes in plans and goals as appropriate for a particular purpose (Messick, 1984). This knowledge reflects the executive thinking processes outlined by Sternberg (Quinby, 1985).

4. Significance of knowledge structuring and structures

-Knowledge appears to be constructed by the learner. This means that knowledge is integrated into an already present cognitive structure which reconfigures itself to incorporate the newly encoded material or reconfigures the new knowledge to fit the present cognitive structure. Another way of saying this is that knowledge is "learned" by combining what one already knows with new information. An important implication of this premise is that what is already known influences what is learned, how it is stored, and its meaning and potential uses to the individual. Piaget's theories concerning assimilation and accommodation (Wadsworth, 1979; Flavell, 1963) are supported by this evidence.

-Knowledge structures have affective as well as cognitive elements. When affect is aroused in connection with a concept, evidence indicates that storage of the concept in memory is more assured and complete. This is attributed to a deeper level of information processing that occurs when affective dimensions are involved in the encoding and storage processes (Anderson, 1980).

Knowledge structures embrace both declarative and procedural knowledge. They appear to represent systems of images, cues, assumptions and rules for interpreting or acting on new information. These integral systems are called schemas and scripts (Anderson, 1980; Messick, 1984) in the information processing literature. Schemas store the predominant features of a category or concept. Scripts store the predominant sequence of events in a particular kind of situation. They enable the individual to match the features in descriptions or experiences they encounter with a stored set of features in order to identify and interpret the descriptions or experiences. Pattern matching is a term sometimes used for this process. A schema or script that a person possesses is invoked when a sufficient number of its features are matched by information present in a situation, or when specialized activation mechanisms have been learned. Schemas and scripts free conscious attention for the novel aspects of a phenomenon and enable one to know when something is missing (Anderson, 1980; Messick, 1984).

The development of schemas and scripts reflect two major mechanisms: generalization, in which schemas and scripts become broader in their range of applicability, and discrimination, in which schemas and scripts become more accurate, precise and exact in their application (Anderson, 1980; Messick, 1984). They become organized in complex patterns, hierarchies and networks which facilitate their continual reorganization. This reorganization makes it possible to apply schemas and scripts to multiple types of problems and situations and to bring multiple perspectives to to the identification and solution of a problem (Messick, 1984).

-Knowledge is structured differently in novices and experts and this difference accounts, at least in part, for their differences in performance. The difference appears to lie in the nature of the knowledge structure and the number of linkages or associations between bits of stored knowledge and reflects the stages or levels of learning in a knowledge domain. The knowledge of novices appears to be more declarative in nature and more discreetly structured than that of experts, novices having fewer links between bits of stored knowledge in the cognitive structure and much less integration of declarative and procedural knowledge. Experts possess more elaborate, integrated and complex knowledge structures that contain fewer redundant and irrelevant dimensions than novices. Consequently, where novices are able to access only one bit or small chunks of knowledge at a time and have a more difficult time discriminating relevant from irrelevant information, experts are able to access several bits or large knowledge networks containing few irrelevant components upon encountering only a single environmental cue. Figure 2 illustrates these differences in knowledge structures. Figure 2 also illustrates the functions of cues and codes discussed earlier in this chapter in connection with context (see page 16). A further obvious but important difference is that experts simply possess larger amounts of accumulated knowledge than do novices. This also contributes to their having more information available to them at any given time than do novices. Thus, experts are more proficient in identifying and formulating problems and in generating solutions that have a high probability of being successful while novices may never access critical pieces of knowledge needed to identify or solve a given problem.

-Mental processing routines, attentional focus and other control processes are more efficient and automatic in experts than they are in novices. For example, attentional resources are limited and can only be focused on a limited number of things at a time. Experts determine what to focus attention on in a problem or situation based on what features are likely to be more informative. Novices don't know what are likely to be the more informative features and thereby focus their attention less strategically. Further, experts are able to automatically focus their attention and process already stored information leaving more of their conscious processing resources for dealing with the unique aspects of a problem. In contrast, novices must use conscious processing resources for determining what to focus their attention on, and for processing information that they have not yet stored. For novices, a great many features in a situation are likely to be unique, including ones which are common across a class of situations and which, for experts, have become routine, unconciously recognized aspects. Experts also possess effective procedures for transforming declarative knowledge of concepts and principles into procedural knowledge that renders the concepts and principles usable in concrete situations.

These differences in the knowledge structures and mental processes of experts and novices is reflected in behaviors that lead to more effective and faster problem solving in the case of experts and less successful, slower problem solving in the case of novices. Observations of novices' and experts' approaches to problem solving indicate that novices tend to analyze concrete specifics of a problem whereas experts tend to analyze more abstract representations of a problem. Further, because of the larger chunks in which they store information, experts are able to hold more key information in short term memory and recall more complicated events and elaborative detail than novices (Anderson, 1980).

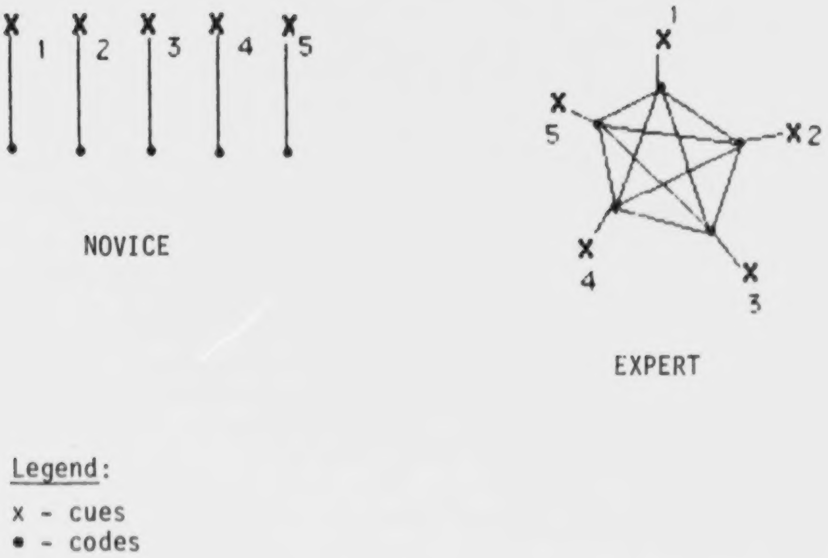

Figure 2. Novice and expert knowledge structures.

5. Differences in processing styles

Evidence points to individual differences in information processing styles. One type of style difference that has been identified is different degrees of emphasis on visual processes and auditory processes (Lachman, Lachman & Butterfield, 1979). This finding supports the recommended educational practice of providing learners with both visual and verbal experiences as well as other sensory experience (e.g. tactile--kinesthetic) with new concepts.

Research on cognitive style differences from the 1950's and 60's and more recent work on learning styles suggests that, while there are general, over-arching and common processes and functions associated with information intake, storage, processing and application, there are also individual differences within these broad processes. The cognitive style research produced concepts and continua which represented dimensions along which people differed in their cognitive style (Goldstein & Blackman, 1978). Examples of these dimensions included field dependence and independence, impulsivity and reflectivity, leveling and sharpening, scanning and focusing.

The more recent learning style research has resulted in the development of cognitively-oriented learning style profiles. In general, cognitive style and learning style have not been shown to be related to intelligence. Two of the more common and cognitively oriented learning style theories are Gregorc's, (1979, 1985) and Kolb's (1976, 1981, 1984).

Recent research (Gregorc, 1979) indicates that four distinctive learning styles exist among students. Each particular style has its own characteristics and all individuals have a style preference. As a result of an individual's preferred learning style he or she is more comfortable with certain instructional strategies than others.

Gregorc's theory addresses two sets of qualities: Concrete and abstract perception, and sequential and random ordering orientation. The qualities have to do with how individuals perceive information (concrete or abstract), and how they arrange it in memory (sequential or random). Four learning styles are identified in Gregorc's research:

Concrete - sequential

Concrete - random

Abstract - random

Abstract - sequential

Concrete/sequential - These individuals react well to specific instructions, orderly activities, and real life problems. Practical details help this learner to achieve success with minimal distress. They enjoy hands-on laboratory activity and prefer information presented in a technical manner. Approximately 25-30% of all learners prefer this style.

Concrete/random - These individuals prefer to work on many projects at once They have many "irons in the fire" and are often bored if limited to one assignment. They enjoy open-ended assignments which encourage creativity and problem solving. If bored, these students can become behavior problems in the classroom. Approximately 15-20% of all learners prefer this style.

Abstract/random - These individuals are sensitive and emotional. They are personable individuals who need to feel welcome in the classroom. They thrive on personal attention, chances to relate with other people, and use of fantasy or imagination. Abstract/Random learners enjoy group activities, role playing and personalized work. Approximately 25-30% of all learners prefer this style.

Abstract/sequential - These are logical, intellectual, structured individuals. They need to have ideas and concepts structured in a logical way. Abstract/sequential learners enjoy reading, writing, and working alone. Approximately 25-30% of all learners prefer this style.

Kolb also identified four learning styles: Converger, diverger, assimilator and accommodator (Kolb, 1976, 1984). Kolb has identified associations between these four learning styles and occupational groups.

Convergers' strength is the practical application of ideas. They do well in situations where one right answer or a single solution to a question or problem is needed. This style has strength in hypothetical-deductive reasoning, prefers things to people, and tends to specialize in the physical sciences. This style is a characteristic of many engineers.

Divergers have strength in imaginative ability. They do well in situations that require idea generation. This style is interested in people and tends to specialize in the arts and humanities. This style is characteristic of many counselors, personnel managers and organizational consultants.

Assimilators excel in creation of theoretical models, inductive reasoning, and in assimilating seemingly disparate ideas into an integrated whole. This style prefers ideas to people, is less concerned with the practical use of theories than with their structure, logic and precision and tends to be reflected in people in the basic sciences and mathematics and in research and planning units of organizations.

Accommodators' strengths are in doing things, in carrying out plans and ideas and in adapting to varying circumstances and situations. Approaches to problem solving are trial and error oriented. At ease with people, this style is characteristic of many sales and marketing personnel.

Although learning style patterns have been shown to be relatively stable, they are subject to change over time and as a result of intensive exposure to particular environments. They have implications for the design of learning situations.

In summary, information processing theory is concerned with how knowledge is stored and coded in the brain, how events, situations, conditions are interpreted, given meaning, and represented in the individual's cognitive structure, and how information is combined, recombined, created, adapted, expanded and related. A new and somewhat physiologically oriented definition of learning is suggested by the findings from information processing research. This definition portrays learning as involving: 1) an encoding process by which the quantity of bits of knowledge that are stored in the brain is increased (i.e., accretion); 2) an association process resulting in a wider range of environmental cues linked to stored knowledge and an increase in the number of associations or linkages between stored knowledge bits leading to larger knowledge networks; and 3) an integration process in which declarative knowledge of concepts and facts becomes interwoven with procedural knowledge of skills. Further, the concept of learning is becoming more developmental in nature. Messick (1984) characterizes this shifting concept of learning as a developmental psychology of performance changes involving the study of changes that occur as different knowledge structures and complex cognitive strategies are acquired, and the study of conditions that affect these transitions.

Traditional concepts of learning and much educational practice address only the accretion aspect of this broadened definition of learning. The role of vocational education in addressing the other two aspects appears to be particularly promising and worth concentrated investigation concerning the degree to which vocational education contributes to these two more complex aspects of learning and ways to improve that contribution.

Human Problem Solving Theory and Research

Problem solving research and theory may be identified as having three major aspects: The nature of the problem, problem solving methods, and the problem solver. Like information processing theory, research regarding human problem solving highlights the relationship between conceptual knowledge and mental processes.

An individual may possess a high level of general problem solving ability. However, when the problem situation requires specialized knowledge for interpreting information about the situation, the individual who lacks the specialized knowledge may be unable to arrive at appropriate solutions (Frederiksen, 1984; Greeno, 1980b; Messick, 1984; Norman, 1980).

1. Nature of the problem.

Newell and Simon (1972) distinguish between well-defined and ill-defined problems. Well-defined problems are ones where a test already exists that is performable with a relatively small amount of processing effort that will determine whether a proposed solution is indeed a solution. Ill-defined problems are ones for which no such tests exists.

Table 1. Characteristics of well- and ill-structured problems.

Well-structured Problems	Ill-structured Problems
definite initial situation is given; all components needed to produce the goal are contained in the initial problem situation	incomplete initial situation is given
definite goal situation to be achieved/what is desired/what conditions must exist for the problem to be considered solved are given	vague or unspecified goal; no specific situation that can be used as a target for problem solving activity is given
specified operators that can be used to transform the situation are given; information about means or tools or operations with which the problem must or can be solved are given; information about the conditions under which the problem must be solved are given; information about access to resources is given	incomplete or no information about means for solving the problem is given; problem solver must generate substantial amounts of the material needed to obtain a solution and determine how the materials are to be arranged

Wickelgren (1974) distinguishes between formal and ill-defined problems and points out that, to the extent that ill-defined problems can be turned into formal problems, formal problem solving methods might be used. He characterizes formal problem types as action-oriented or conclusion-drawing. He indicates that formal problems may be of the proof type where the terminal goal is completely and explicitly specified or they may be a find type of problem where terminal goal is not completely nor necessarily explicitly specified. He does not deal with ill-defined problems which he points out include practical problems.

Table 1 contrasts well and ill-structured problems in terms of their characteristics (Greeno, 1980a; Newell & Simon, 1972; Wickelgren, 1974). Most problems that confront learners in life are of the type that do not explicitly identify all the information needed for solution. They are the ill-defined type of problem where the situation is not specified and described, where the goal is often not specified and where no test exists for determining whether a proposed solution is, indeed, a solution. As such, they require creative rather than routine problem solving (see Chapter II, page 8, for discussion of these two types of problem solving). Individuals must ferret out of a situation that information which is relevant to identifying the problem and finding potential solutions, and then construct solutions based on the knowledge they possess that bears on the problem elements. While research and theory have recognized that problems differ in nature, no extensive and comprehensive taxonomy of problem types has been identified; nor is it clear what a useful basis would be for structuring such a taxonomy. Greeno (1978b) has discussed this problem and questioned whether "... principles that operate in solution of well-structured problems also are significant in ill-structured problems or whether fundamentally different principles are needed for understanding the solution of ill-structured problems," (p. 65).

2. Problem Solving Process and Methods

Research on problem solving has produced a general theory of problem solving which is described below (Newell & Simon, 1972). This theory characterizes problem solving as having four major stages: representing the problem, reducing the total problem to selected aspects that will be worked with in detail, selecting a method or methods for solving the problem, and generating and evaluating potential problem solutions. These major processes have numerous sub-elements. Representing the problem involves perceiving, defining and organizing factors embedded in the problem situation, categorizing and establishing a context for the problem, and selecting an appropriate classification for the problem. An example of the latter might be seeing declining collegiate enrollment as a marketing and recruitment problem or as a demographic problem. Obviously, the solutions generated by collegiate institutions coming from these two problem representations may be quite different. This stage is concerned with problem finding and definition.

Reducing the problem involves identifying the aspect(s) of the problem to be worked with and includes definition of the key elements in the present state of affairs and the desired state of affairs, the cause-effect relationships present in the situation, the goal, and the resources available or that could be developed. This process is sometimes referred to as constructing the problem space. This stage is still concerned with problem finding and problem identification but at a more specific level than stage one. This stage more specifically sets the parameters within which the next, solution-finding focused stage occurs.

Selecting method(s) for solving the problem, the third stage, involves making decisions about an appropriate approach to generating problem solutions given the type of problem representation and its subspace that has been constructed. Two very general methods have been identified which encompass a host of more specific methods. These two general methods are changing the problem representation and changing the method within a particular representation. Changing the problem representation involves going back to the original information and reclassifying it. In the example given above this might involve representing what had been seen as a marketing and recruitment problem as a demographic problem. Three basic approaches to the second general method, changing the method within a particular problem representation, are recognized: 1) using an algorithm, which involves recognizing a problem as a particular type and matching it with a clearly established method known to consistently yield an appropriate solution; this method is appropriate for well-defined problems where the terminal goal is completely and explicitly identified. 2) generating all possible solutions and testing each (this is a practical method when only a few solutions are possible but an extremely impractical method when an infinite number of potential solutions exist or when potential solutions are not readily identifiable); and 3) finding a solution path. The latter method is needed when no algorithm is available, when the generate and test method is impractical, or when problems are ill-defined or lack critical elements of information. Within the solution path strategy, several approaches have been identified. These include means-end analysis, working forward, working backward and planning. These solution path strategies are often used in combination with one another.

Means-end analysis involves identifying subgoals and means that achieve them, thereby moving a state of affairs successively closer to the final desired state. Working forward involves starting with the current state and specifying the features of the desired state so solutions that achieve these can be recognized. Working backward involves starting with the desired state and trying to construct states that precede it in order to trace a solution path. Planning involves abstracting the problem in general terms and working out a solution and then applying the abstracted solution in the actual problem.

Wickelgren (1974) has provided a range of problem solving methods that reflect the general problem solving methods discussed here in relation to different kinds of formal problems.

Generating and evaluating solutions involves applying a problem solving method to construct potential solutions and then testing the potential solutions to see if they meet the requirements for the problem to be considered solved. Well-structured problems make it clear what these requirements are. Ill-structured problems, on the other hand, provide little or no guidance as to what these requirements might be.

3. Problem Solvers

Research that has focused on problem solvers indicates that knowledge of concepts and relationships relevant to particular settings, contexts and problems may be a necessary prerequisite to being able to solve problems effectively. That is not to say that problem solving processes are not important. However, there is evidence to suggest that skill in processes alone, without conceptual knowledge about elements in situations or states of affairs may be insufficient for problem solving (Frederiksen, 1984; Glaser, 1985; Messick, 1984). For example, Elstein, Shulman and Sprafka (1978) discovered that wide variability existed in physicians' ability to solve diagnosis problems across different types of illness. That is, a physician might be very good at diagnosing polio but not very good at diagnosing stomach ulcers. The questions underlying the study were: "What are the characteristics of effective physicians?" and "What are the components of clinical (diagnostic) competence?" The focus of their study was on individuals versus groups and on forms of decision making that involve the processing of information to make judgments. The researchers were concerned with tracing and describing the intellectual processes used by clinicians to render judgments and make decisions or solve problems. Their research approach is applicable in studying both a total, large scale task or only a subtask. Their research methodology focused on investigating the sequential character of information-seeking leading up to judgments or decisions and used simulation to represent the task environment. Their findings indicated that problem solving of diagnosis-type problems was characterized by deductive reasoning in which hypotheses were generated early in the problem solving process and then tested.

Messick (1984) also refers to the specificity of problem solving skill. He suggests that the ability-knowledge complexes which make a person competent in a particular field may differ markedly and qualitatively by subject area. Thus, problem solving in physics may be quite different from problem solving in medicine or the social sciences. Other researchers have identified a similar phenomena (Tuma & Reif, 1980).

Different problem solvers pay attention to different features of a problem. For example, novices have been found to sort problems on the basis of surface features in contrast to experts who categorized problems on the basis of fundamental principles (Chi, Feltovich, & Glaser, 1981; Chi, Glaser & Rees, 1981). This difference enables experts to connect with the problem situation an array of factual knowledge and knowledge about solution methods that they have stored in their memory.

In summary, research on human problem solving suggests the importance of the nature of the problem to the information and procedures needed to solve it. Secondly, this research makes clearer why real world problems are often so difficult to work with and offers useful information in thinking about how that difficulty might be reduced. Third, it provides a degree of precision in understanding of problem identification and problem solving processes that has not previously characterized knowledge about these processes. Fourth, it provides useful information concerning the prerequisites and conditions needed by people in order to be competent problem identifiers and problem solvers. All of this knowledge, and that resulting from information processing research, promises to be useful and applicable in developing better understanding of the nature of problems central in vocational education, what is required in order to identify and solve them, and how expertise in identifying and solving such problems might be developed.

CHAPTER IV: AGENDA FOR INQUIRY

Overview

The preceding sections of this document provide an overview of educational and learning problems, and theory and research findings concerning the mechanisms by which people take in, process, store, combine, retrieve, and use information in interpreting their experience, identifying and solving problems, making decisions, performing operations, etc. This chapter presents an agenda for inquiry that: 1) reflects existing knowledge about higher order thinking skills outlined in the previous chapters; 2) identifies potential ways of answering the question, how and to what extent does vocational education involve the application of higher order thinking skills, and 3) will lead to developing curricular and instructional models in vocational education that explicitly incorporate higher order thinking.

The inquiry agenda focuses on identification, description, understanding and development of intellectual aspects of competence within knowledge and problem domains and contexts that are relevant to vocational education. Competence, as discussed in Chapter II is a concept underlying the research agenda because it is a broad concept which encompasses the intellectually-focused concepts defined and discussed in Chapter II, as well as dispositions and other kinds of capabilities needed by learners in their work and family situations (Raven, 1984). As the rates of knowledge growth and technological and social change become more rapid, definitions of competence are likely to increasingly incorporate a person-environment interaction perspective such as those of Klemp (1984) and Waters and Sroufe(1983) and to reflect the ability to function capably in a rapidly changing environment. The definiton of competence on which this inquiry agenda is based is complex, integrated patterns of knowledge, cognitive abilities, and dispositions that guide, organize and form effective actions in work and family situations.

Messick's (1984) concept of competence as a continuous variable rather than a standard of adequate performance is the meaning associated with the term as it is used in this inquiry agenda (see competence section in Chapter II). The competence continuum of interest in this inquiry agenda extends from the novice or beginner to the expert or authority (Pearson, 1984) because this is the learning continuum of interest in vocational education.

The inquiry agenda is divided into three interrelated parts, each introduced by a general research question. These three parts are designed to address objectives b and c identified in chapter I (p. 1). Objective a was addressed in Chapters II and III. The focus of the three parts is as follows:

Part I. Identifying and organizing problems and contexts central in vocational education and their requirements.

Part II. Describing, documenting and understanding knowledge, cognitive abilities and dispositions required by problems and contexts central in vocational education.

Part III. Identifying, developing and assessing curricular designs and instructional processes that facilitate development of the knowledge, cognitive abilities and dispostions required by problems and contexts central in vocational education.

The first part concerns identification and organization of problems and contexts with which vocational education is concerned and identification of the knowledge, cognitive abilities and dispositions required by those problems and contexts. This component of the inquiry agenda reflects research findings and theory which suggest that problem solving ability is knowledge domain and problem specific, and that context influences mental storage and retrieval of knowledge.

The second part of the inquiry agenda concerns description, documentation, and understanding of the knowledge, cognitive abilities and dispositions required by the problems and contexts identified in the first part of the agenda. Part II will provide a knowledge base from which to identify the requirements of the problems and contexts identified in connection with Part I. The second part draws on research findings concerning knowledge stored in memory, knowledge acquisition processes, novices and experts, and problem identification and solving processes. Whereas the focus of research in the first part of the inquiry agenda is on the nature of problems, the focus of research in the second part of the agenda is on the nature of the problem identifier and solver as a knower, learner, information processer, and problem and solution finder.

The third part of the inquiry agenda focuses on affecting the development through education of the knowledge, cognitive abilities and dispositions required by the problems and contexts identified in Part I and described, elaborated and documented in Part II. Part III focuses on development of curricular designs and instructional processes and assessment of learning that occurs through them. The objectives and variables included in the inquiry agenda are summarized in Appendix A.

The inquiry agenda presented in this chapter is intended to provide a framework within which many specific studies by many different and independent researchers can be developed, interpreted, and integrated. The agenda provides broad, general research questions from which questions to guide specific studies can be generated. The framework is provided to facilitate the accumulation of a cohesive, interrelated knowledge base regarding thinking processes and vocational education. Because the agenda's role is to facilitate the development, design, and interpretation of research, a greater number of concepts, variables and research methodologies are suggested in each section than would normally be incorporated in a single study. Selection of a component of the inquiry agenda and concepts, variables and methodologies is assumed. The problems identified in Chapter I might serve as a general framework for research problem identification. The inquiry agenda is focused on research questions and objectives. The reader is guided in the agenda to research studies that provide additional information or examples relevant to a concept, variable or method. It is intended that the agenda serve as a source document for the development of thesis and dissertation research, research by professional researchers and research by educational practitioners that concerns thinking and vocational education.

Because the research literature in cognitive psychology and other areas relevant to thinking skills is growing and changing very rapidly, revisions will undoubtedly be needed in this agenda before long. Even as the agenda goes to press there is work emerging that should have been incorporated. The reader should also be aware that all exisitng research which could possibly have been included is not. This burgeoning area of research is already vast and rapidly becoming more so. What is included represents a starting place, and concepts that have particular promise for instructional application.

A rigid sequence of research efforts with respect to the three parts of the agenda is neither intended nor recommended. Knowledge developed in relation to each part will inform research efforts related to the other parts. However, there is a general progression of knowledge development that is reflected, beginning with research question one and progressing sequentially to research question 3. This progression would suggest that early research efforts should focus more heavily on research question 1 with research questions 2 and 3 receiving more emphasis as knowledge and problem domains and contexts are clarified.

Agenda for Inquiry

Part I. Identifying and Organizing Problems and Contexts Central in Vocational Education and Their Requirements

Research Question 1: How can problems and contexts central in vocational education be identified and organized in order to:

a) address rapid technological and social change
b) facilitate understanding of them
c) identify and develop expertise for working with and within them?

At present little is known about alternative ways in which problems and contexts central in vocational education might be identified and structured. While there are general conventions within the various fields of vocational education for structuring curriculum, few of these are problem based. Further, there have been few philosophical or empirical investigations that have identified relationships between problems, contexts, and their requirements or that have developed and systematically tested alternative ways of structuring these three elements into some cohesive whole. Yet, it is clear in the cognitive science literature that these three elements are related to knowledge storage and use.

The increasing rate of knowledge growth and technological and social change suggests a need to structure problem and knowledge domains in a way that defines problem categories at broad, general, functional levels which do not change so rapidly over time and which can relate to more specific problems that are likely to change more rapidly. In other words, problem categories need to allow for the emergence of problems that will be identified in the future and for their requirements. Further, problems need to be identified, described and organized in such a way that complex, integrated patterns of knowledge, cognitive abilities and dispositions that guide, organize and form effective actions in working with them can be identified and used as a basis for curricular and instructional design. The kinds of competence needed for a problem that has not yet been identified may be quite different from that required by an already familiar problem.

The literature in cognitive science has provided limited work on taxonomies or typologies of problem types, but it does suggest that such a structure may be useful in understanding expertise or developing it. The idea of problem types and taxonomies is not new (Greeno, 1980b; Reitman, 1965; Wickelgren, 1974). Taxonomies and typologies that have been identified or suggested are at extremely broad, general and generic levels (e.g., Greeno, 1980b; Newell & Simon, 1972; Wickelgren, 1974). Many discussions of problem type do not move beyond brief discussions of well- and ill-defined problems (see Chapter III and research question 3, subquestion c, for a comparison of these two problem types). Problem types that have been identified tend to be related to formal problems (Wickelgren, 1974) (such as math or logic problems) and ignore "messy" types of problems where very little information needed for solving or even identifying the problem is given. The latter type of problem is characteristic of many problems that arise in real life and that are of concern in vocational education. Greeno's (1978b) comment referred to in Chapter III in the problem solving section addresses the significance for the problem solver of differences among types of problems and questions whether principles that operate in solution of well-structured problems are the same as or different than principles needed for understanding the solution of ill-structured problems.

Problems might be differentiated on other dimensions in addition to the amount of structure, or given information, they contain (see Table 1 in chapter III). The usefulness of a problem taxonomy or typology set at a somewhat less general and generic level for understanding problems and developing in problem solvers the ability to work with them should be explored. For example, mechanical, electrical and electronic repair personnel all face system failure/trouble shooting/diagnostic problems that may have similar general features. Identification of the general features could provide a "system failure/trouble shooting/diagnosis problem" framework within which specific elements of mechanical, electrical and electronic system diagnosis and repair problems might be identified.

The system failure or trouble shooting problem is an example of one potential problem type. Such a problem seeks to isolate the system, identify the breakdown or malfunction in the system, identify the cause(s) of the breakdown, and determine what actions or materials can be applied in the situation to change the state of the malfunctioning or nonfunctioning system component(s) to a functional state. Important features of such problems would seem to include identifying the system, its components, the potential causes of system failure, cues that indicate each cause, the probability of each cause occurring, and approaches for removing the cause. While the specifics of each of these features would be different for a mechanical system failure problem and an electrical system failure problem (and different for different kinds of mechanical systems and different kinds of electrical systems), these same general features would seem to be common.

The amount of structure in a problem could vary quite independently from variation in problem type. For example, system failure problems might be more or less structured depending on the amount of information that is explicitly provided in the problem situation. It would be quite a different matter to figure out why a car doesn't start if you know the battery is dead as opposed to not having any information beyond "it won't start." Further, although the goal in a system failure problem is usually readily known (i.e., make the system functional), the constraints under which specific problems may need to be solved would also be a factor in the amount of structure a problem reflects. For example, if there is no testing equipment available for determining if a car's components are functional, the problem solver with the car that won't start has more constraints than if unlimited testing equipment is at hand.

One broad dimension on which problem types might be differentiated is whether or not they require a norm or standard to be set or give or imply a norm or standard and require it to be met or held. Within these two broad categories, problem type subcategories might be developed. Some examples of potential problem type subcategories within these two broad categories that may be especially relevant in vocational education are identified and illustrated below:

-*Norm or standard holding or implementing problems* (Vickers, 1983) are those where adjustments and changes are needed or where new aspects need to be created in order to *maintain a given norm or standard*. Examples of such problems include most *system failure problems* of the type discussed above, *regulation type problems* including determining what is causing falling farm enterprise profit levels and if and how they can be reversed, regulating the nutritional status of a family by adjusting food intake to yield a given nutritional level, monitoring and adjusting the sanitation practices in a food service operation to meet public health standards, and determining how building codes can be met within new resource constraints in the construction of a building. Many *design problems* (Perkins, 1986; Reitman, 1965) are also of this type: e.g., producing a building design that meets code requirements and resource and site constraints; designing an environment for a child that stimulates and supports certain kinds of development; designing a system of observation and care for new livestock that reduces the incidence of disease and loss; designing a food plan for a family consistent with family preferences, budget and time limitations, availability of food products, special dietary needs, and established nutritional norms. *Translation problems* (Dillard, Bhaskar & Stephens, 1982) also are of this type and are concerned with changing the form of information, matter or processes. Examples include figuring out the ways a set of financial data should be entered in a ledger to meet legal requirements and accounting conventions; determining ways of changing a sheet of metal into a pre-designated shape or form.

-*Norm or standard setting problems* (Vickers, 1983) are those where norms or standards are not given and must be identified. These problems include situations where no norms or standards exist or in which it is determined that present norms or standards are no longer functional or acceptable but new norms or standards are not given. Examples of such problems include creating a new system (as opposed to fixing the old one as in the trouble shooting problem type); figuring out the profit levels a farm enterprise must yield in order to justify its continuance; determining a desired or acceptable living standard for a family; determining the qualities desired in a parent-child relationship; determining the level of quality in operations, products or services that will be considered acceptable in a manufacturing or service-producing business operation.

These examples of problem types and categories illustrate how problems that may share general features might be grouped together at general levels. One basis for grouping problems that appears to be potentially helpful is the type of goal the problems involve. Research is needed to develop alternative models of problem types and to test their usefulness for developing schemas (see Chapter III for a discussion of schemas) for identifying and solving different types of problems. Such research will also help vocational educators clarify the goals and purposes of vocational education and understand, clarify and articulate the kinds of problems with which vocational education is concerned.

Studies regarding the problems of concern in vocational education should be designed and conducted to yield the following elements: 1) significant, recurring types of problems that arise within contexts relevant to vocational education. At a very general level, these contexts have been most frequently identified as the work context and the family context. Careful consideration should be given to the types of work contexts and the types of family contexts of particular concern and priority in vocational education and to the development of systematic processes for establishing and revising these priorities as technological and social changes occur; 2) key features central to each problem type and the different forms these features can take; 3) types of knowledge, cognitive abilities, and dispositions (e.g., interests, motivations values, priorities) needed to work with the problem type.

Suggestions for approaching research on the first element have already been provided in the discussion of problem types. In addition to the conceptual approaches identified with problem categorization, empirical observations of contexts using anthropological and other qualitative research methodologies and use of futures research methodologies for projecting their future character will be needed. Context-focused research needs to describe the structure of contexts and predominant relationships, operations, and situations within them and the meanings of the relationships, operations and situations to those who function within them and to those who affect or are affected by them. A useful level at which to identify contexts may be one which differentiates between contexts that vary in their priorities, resources and constraints.

Research on element two, key features of problem types, will be a true pioneering effort. A few references (e.g., Greeno, 1980b; Newell & Simon, 1972; Reitman, 1965; Rogoff & Lave, 1984) will be helpful starting places.

Element three will be informed by research directed at elements one and two and that directed at research question 2. It is addressed at a general and generic level by the discussions in Chapters II and III. In addition, Pottinger (1979) provides a useful overview and evaluation of alternative techniques and considerations in defining competence that would be relevant to element three.

Part II. Describing, Documenting and Understanding Knowledge, Cognitive Abilities and Dispositions Required by Problems and Contexts Central in Vocational Education

Research Question 2: What knowledge, cognitive abilities and dispositions, and relationships within and among them, guide, organize and form effective actions in working with problems and in contexts identified through research on question 1?

Whereas research question 1 focused on problems, research question 2 is focused on the person as a knower, learner, information processer, and problem identifier and solver in relation to problems and in contexts identified in connection with research question I. Research question 2 is concerned with three dimensions of the person:

a) stored knowledge,

b) knowledge acquisition processes,

c) processes used by the problem solver in identifying and solving problems.

These three dimensions reflect the research and theory reviewed in Chapter III and that have consistently been associated with differences in levels of expertise. The three dimensions are interrelated. Stored knowledge influences knowledge acquisition processes by influencing where attention will be focused and what information will be sought. Knowledge acquisition processes influence knowledge storage in memory and activation of stored knowledge. The problem solving processes are guided by stored knowledge in directing purposeful attention and information-seeking in relation to problem identification and solving. A subquestion of research question two is posed regarding each of the three dimensions.

Subquestion a: What attributes and relationships among them characterize the stored knowledge of individuals who are classified as experts and novices with respect to problems and contexts identified in connection with research question 1?

This subquestion focuses on the knowledge the problem solver possesses in memory. Stored knowledge has been identified as a significant factor in perceiving and processing new information, in speed in problem solving, and in differentiating levels of expertise. The cognitive psychology literature does not distinguish between knowledge and information. Likewise, the two terms are used interchangeably in this document.

Key characteristics of stored knowledge that have been associated with level of expertise include: Content (what is stored), amount (quantity stored), arrangement, complexity, and degree of integration (how it is stored). Content refers to the labels, facts, concepts, principles, images, experiences, schemas, and scripts (see Chapter III) a person has stored in their memory. Amount refers to the quantity of knowledge within and relevant to a problem and context that an individual has stored. Arrangement refers to the clusters and groupings of stored knowledge (i.e., which concepts are stored together, kinds of associations between concepts that are stored, such as hierarchical, sequential, condition-action associations). Complexity refers to the number of levels in which knowledge is stored. For example, in hierarchical arrangements, more general, abstract levels of knowledge might be stored in relation to several more specific levels. Degree of integration refers to the extent to which large clusters and groupings of stored knowledge are linked together and the extent to which declarative and procedural knowledge are interwoven (Anderson, 1980; Messick, 1984). Compared with novices, experts have been shown to possess a larger quantity of knowledge that is stored in bigger "chunks" which are more interrelated and have a greater number of hierarchical levels. Studies that incorporate one, several, or all of these variables will be useful but will vary in scope and complexity and the amount of information they yield.

In addition to studies that describe and compare novices and experts on each of the stored knowledge characteristics, studies of interrelationships between the characteristics should be conducted and comparisons between experts and novices made with respect to the identified interrelationships.

Numerous ways of observing these descriptive dimensions of stored knowledge so that those of experts and those of novices can be compared have been identified in the information processing literature (Anderson, 1980; Lachman, Lachman & Butterfield, 1979). Only illustrative examples are mentioned here. With respect to content, Anderson (1980, p.149) suggests that the scripts a person possesses can be elicited by asking the person to name the most important events in an episode. This technique applied to vocational education is illustrated by the following questions: Name twenty things you would do in the order you would do them if a malfunctioning PC Jr. computer was brought in for repair; name twenty occurrences you would anticipate in the order in which you would expect them if you were put in charge of the care of a three year old you did not know and you were to be with the child between the hours of 4p.m. and 10 p.m.; identify fifteen things you would consider in the order in which you would consider them in deciding if sunflower raising is a viable farm enterprise in central Minnesota. Responses to such questions would be analyzed for what is included and what is not included, sequences and priorities indicated. These analyses might also be compared with the results the person achieves in finding the problem with the PC Jr., being in charge of an unfamiliar three-year old child, and making a decision about sunflower raising as a farm enterprise. Another way of observing scripts would be to ask the individual to develop a flow chart (Posner & Rudnitsky, 1982). This could be analyzed for both sequence and content of stored knowledge.

Concept mapping (Novak & Gowin, 1984) is a technique for observing content and quantity of stored knowledge as well as its arrangement, complexity and integration. This technique involves having the individual draw a "map" or diagram of a concept and then analyzing the map for its content and structure. Detailed procedures for developing and scoring such maps are provided by Novak and Gowin. Variations of this technique include asking students to draw diagrams or other types of schematics which represent their idea of a system, object, place, relationship, etc.

Additional approaches for observing stored knowledge and illustrations of the techniques mentioned here are provided in West and Pines (1985).

Identifying individuals at different levels of expertise is likely to involve special challenges since the criteria for classifying levels of competence is what the studies will attempt to discover. Despite the fact that the specific criteria may be unknown at the beginning of such studies, accurate classification will be critical to the validity of the results of the studies. Bhaskar, Dillard and Stephens (1983), Dillard, Bhaskar and Stephens, (1982), Elstein, Shulman and Sprafka, (1978), and Stephens, Bhaskar and Dillard (1981) all provide examples of criteria and procedures for identifying different levels of expertise that may be useful.

Subquestion b: What relationships and attributes characterize knowledge acquisition processes of individuals who are classified as experts and novices with respect to the problems and contexts identified in connection with research question 1?

Subquestion b concerns processes which facilitate and control selection, entry and retention of new knowledge into a person's stored knowledge structure. These processes are significant for learning and have been associated with differences in levels of expertise in problem solving. Research related to subquestion b will reveal patterns of allocating attentional resources and patterns of information search that are more and less functional in acquiring knowledge relevant to problems and contexts of concern in vocational education.

Attentional Focus

Attention is required for the retention of incoming sensory information. Attention is focused concentration on a phenomenon that is sufficient to notice or heed (Ericsson & Simon, 1984) the phenomenon. Because attention is a limited mental resource, and because there is typically more information entering a person's sensory system than can be attended to, the ways in which attentional resources are allocated determines which sensory information will enter memory and be available for recall at some later time (Anderson, 1980). Hypotheses about the basis on which attention is allocated include the informative value of the incoming information, enduring dispositions or attentional biases of the individual, the individual's momentary intentions, and the evaluation the individual makes of the demands on their attentional capacity (Anderson, 1980; Kahneman, 1970; Norman, 1970).

Variables relevant to attentional focus and on which comparison of experts and novices would be useful in furthering understanding of their differences include: The object of attentional focus (i.e., what is attention focused upon); how long attention is focused on particular thing or aspect; the sequence in which each aspect receives attention; the accuracy and extent of cue perception (were cues accurately perceived and how much about them was noticed?); the degree to which attention is focused on cues or signals indicating factors relevant and critical to understanding a situation or to other purposes; the bases on which attention is allocated; and the extent to which attention-focusing is an automatic versus a conscious behavior. The more that attention can automatically (unconsciously) be focused on aspects known to be informative, the greater the amount of conscious attention resources that will be freed to focus on unknown, unfamiliar aspects of situations and problems (Anderson, 1980; Sternberg, 1985). Studies that incorporate one, several, or all of these variables will be useful but will vary in scope and complexity and in the amount of information they yield.

In addition to studies that describe and compare novices and experts on each attentional focus variable, studies of interrelationships between attentional focus variables should be conducted and comparisons between experts and novices made with respect to the identified interrelationships.

Attentional focus is also incorporated in subquestion c, discussed later, in the context of problem identification and problem solving. Attentional focus is relevant in almost any situation such as those where a person might be observing, reading, monitoring, performing some operation, engaging in some type of interaction, etc. Attentional focusing operates in learning situations, and in casual and purposeful, and routine and nonroutine encounters with actions, ideas, people, things, and processes and procedures in the course of work life and family life. It is through such encounters that new information enters the stored knowledge structure and the first vague awareness of the potential existence of a problem arises.

Research techniques that are especially well suited to observation and comparison of attentional focus patterns of experts and novices include a range of techniques used in information processing studies on attention and perception and reported in Lachman, Lachman and Butterfield (1979) and Anderson (1980), protocols (Dillard, Bhaskar & Stephens, 1982; Larkin, 1979), a tab-item technique which traces information-seeking (and therefore attentional) patterns (Glaser, Damrin & Gardner, 1954), the in-basket technique (Frederiksen, Saunders, & Wand, 1957), and additional techniques used to track the attentional focus of physicians in working on medical diagnosis problems and reported in detail in the Elstein, Shulman, and Sprafka (1978) study of medical problem solving.

Information processing research approaches include exposing a person to a situation, a picture, a reading, etc., and asking them to report what they noticed, to recall or repeat what they saw or read, etc. Protocols are detailed records of the "thinking out loud" and actions of a problem solver recorded by an observer (sometimes accompanied by mechanical recording devices such as tape recorders and video recorders) during the problem solving process. The tab item technique is a prepared series of diagrams and information that the problem solver uncovers serially as he or she works on a problem, recording each diagram and piece of information examined, leaving a record of the sequence in which they were examined. The in-basket technique is a simulation technique that has been used for some time in management studies where the problem solver is given the contents of a manager's in-basket and asked to deal with them. The items attended to are recorded for later analysis. A twenty questions technique was used by Elstein, Shulman and Sprafka (1978) in which the problem solver could ask questions that required a yes/no response.

Appropriate techniques for studying object(s) of attentional focus include the information processing techniques, protocols, the tab item, the in-basket and twenty questions. Time allocation to objects can be studied using protocols and by combining protocols with the tab item and in-basket techniques. Sequence of attentional focus can be studied using protocols, the tab-item, in-basket, and twenty questions techniques. Accuracy and extent of perception will be revealed most directly by the information processing techniques but protocols, tab items and in-basket techniques would also provide useful data.

Relevance and significance of the objects focused upon to a given purpose could be evaluated by an independent expert or could be studied from the problem solver's perspective through protocols combined with stimulated recall. Protocols and stimulated recall (Calderhead, 1981) can also be used to identify bases for allocation of attention (e.g., anticipated informative value of the information, enduring dispositions, momentary intentions, evaluation of attentional capacity) as perceived by the individual, and the extent to which attention-focusing is an automatic versus a conscious behavior. In the stimulated recall technique, a video or audio tape or written record (protocol) is made of the individual's actions and verbalizations. Immediately following the end of the activity or situation, the record is shared with the person who is questioned about what he or she was thinking when focusing attention on each aspect and when changing attentional focus from one aspect to another. In using these techniques to determine the extent to which attention-focusing is automatic, those attention-focusing actions that the problem solver cannot give reasons for or remember in the stimulated recall technique and those that are not represented in thinking aloud protocols may represent attention-focusing that has become automatic (unconscious). The possibilities the stimulated recall technique introduces for the person to generate post hoc reasons for focusing their attention rather than reporting or remembering what was actually their thinking at the time in question should be diminished as much as possible through careful design and question wording (Ericsson & Simon, 1984) and considered in the interpretation of stimulated recall results.

Information-seeking

Given that attention can be focused both on information one is presented with but does not seek, and on that which one actively seeks, information-seeking might be viewed as a special, extended and purposeful kind of attentional focus and as involving initiative on the part of a person to examine some aspect or develop an information base. Information-seeking refers to purposeful self-monitoring, environmental monitoring and scanning, questioning, and other forms of information search with an intent to expand the information one possesses.

Variables relevant to information-seeking and on which experts and novices can be compared include: The type, content and amount of information sought and obtained; the sequence in which information is sought and obtained; the sources from which information is sought and obtained (including one's own memory); the methods by which information is sought and obtained; the ways and formats in which information obtained is recorded; the relevance/significance of information sought and obtained to understanding a situation or to a given purpose, and the accuracy of information obtained; the amount of time spent in obtaining various elements of information from various sources and by various methods; interpretations and evaluations applied to the information obtained; bases for types and amount of information sought, selection of sources and methods, and sequence of information-seeking; and degree of automaticity in information-seeking.

Like attentional focus, information-seeking is also incorporated in connection with subquestion c in the context of problem identification and problem solving processes. Also like attentional focus, information-seeking is relevant to situations involving observation, performance, interaction with ideas, people, things, etc., and to learning and other purposeful situations in general.

Studies that incorporate one, several, or all of these variables will be useful but will vary in scope and complexity and in the amount of information they yield. In addition to studies that describe and compare novices and experts on each of the information-seeking variables, studies of interrelationships between the characteristics should be conducted and comparisons between experts and novices made with respect to the identified interrelationships.

Research techniques that are especially well suited to observation and comparison of information-seeking patterns of experts and novices include most of those already discussed in relation to attentional focus. Data from the protocols, tab item, in-basket simulations and twenty questions approaches can be analyzed for type and content of information sought (What aspects of the situation did it concern? Was it quantitative or qualitative information? Was it precise or general? etc.), amount of information sought (How much information of each type was sought?), sources from which information was sought and obtained (Where did the person look for which type of information and which sources yielded which information?), sequence in which information was sought (In what order was information sought? How did information obtained influence subsequent information-seeking?), procedures or approaches used in obtaining and recording the information, amount or proportion of time spent in seeking different types of information and/or proportion of questions generated which were directed at seeking different types of information. Protocols and stimulated recall techniques can be used to study the interpretations and evaluations applied to information obtained, the bases for information-seeking, and the degree to which information-seeking is an automatic versus a conscious activity in a manner similar to that described for studying these aspects of attentional focus. The degree to which information sought and obtained is relevant and significant to understanding a situation or to a given purpose can be evaluated externally by an independent expert or could be studied from the problem solver's viewpoint using protocols combined with stimulated recall.

Subquestion c: What patterns characterize problem identifying and problem solving processes used by individuals who are classified as experts and novices with respect to problems and contexts identified in connection with research question 1? How are the results of these problem identifying and problem solving processes characterized?

Subquestion c concerns the ability to identify and solve problems. This involves perceiving states of affairs, seeking new information, activating information stored in memory, and integrating and acting on this information. Problem solving involves mental processing of information that leads to interpretations, conclusions, decisions, judgments, descriptions of conditions or states, and the creation of strategies and solutions. Research related to subquestion c will reveal approaches to problem identification and problem solving that are more and less functional for problems and contexts relevant to vocational education.

The problem solving section in chapter III outlines problem solving processes portrayed in the literature as generic across different types of problems. These processes include problem representation, problem reduction or focusing, problem solving method selection, and solution generation and evaluation. Research addressing subquestion c will describe and increase understanding of these processes as they are employed by expert and novice problem solvers in the identification and solution of problems relevant to vocational education. While evidence suggests that there is a general progression through the four processes from representation to solution generation and evaluation, movement of problem solvers through the processes is generally characterized by overlaps and back and forth efforts. Further, it is likely, at least in earlier studies, that all four processes will be of interest because of the interrelationships between them. Later studies may be more precisely focused on a process of particular interest in relation to some problem.

Studies which examine the relationship between characteristics of experts' and novices' stored knowledge and the variables identified with the four problem solving processes discussed below will aid understanding of the relationships between stored knowledge, knowledge acquisition processes, and problem identification and problem solving processes and their results. Such studies should be developed and carried out in addition to studies that focus on only one of these components.

Problem Representation

The problem representation process concerns problem identification. How a problem is identified influences what information about the problem will be sought and what solutions will be considered. Conversely, information that is sought will also influence problem representation. Problem representation involves perceiving, defining and organizing factors given or embedded in the problem situation, categorizing and establishing a context for the problem, and selecting an appropriate classification for the problem.

Variables relevant to the problem representation process and on which experts and novices might be compared include: the amount of time invested by the problem solver in representing the problem; aspects of the problem situation that do and do not receive attention; the sequence in which problem elements attended to receive attention; the amount of time allocated to attending to various problem elements; the type, content and amount of information that is sought and obtained by the problem solver in representing the problem; the sequence in which information is sought and obtained; the sources from which information is sought and obtained; the methods by which information is sought and obtained; interpretations and evaluations applied to information obtained; allocation of time to seeking various kinds of information from various sources;

bases for attention allocation and information-seeking; automaticity of attentional focus and information-seeking; ways and formats in which information is recorded (e.g., to what extent is an external memory, such as paper, used in holding and working with information? How is information organized?); identification of explicit and implicit factors in the problem situation and the sequence in which they are identified; ways in which identified factors are organized; what is identified as desired in the problem situation, as conditions that must exist in order for the problem to be considered solved, and as the conditions under which the problem must be solved; sequence in which what is identified as desired in the problem situation, conditions that must exist in order for the problem to be considered solved, and conditions under which the problem must be solved are identified, the factors that are considered in their identification, and the relationship of problem elements receiving attention and the information sought and obtained to these aspects of the problem representation; the context that is established for the problem and its categorization and relationship of problem elements receiving attention and information sought and obtained to the context established and its categorization; the way the problem is categorized and relationship of problem elements attended to and information sought and obtained to the problem categorization.

Studies that incorporate only one or some of these variables are likely to be considerably less useful than are more comprehensive studies because of the assumed interrelationships between the variables.

Problem representation processes are particularly challenged by ill-structured problems which provide little information about states or conditions or the problem context. Problem representation processes for such problems involve generation of these elements by the problem solver from whatever information is given, the problem solver's stored knowledge, and information sought out by the problem solver. Problem solvers also cognitively "represent" well-structured problems but this involves more emphasis on careful and accurate encoding (entering information into the cognitive structure) and organization and categorization of information already given in the problem and less emphasis on generation of new information. Studies of experts and novices should be done using both kinds of problems so that the differences in what is required by each of these types of problems can be better understood. The discussions of well- and ill-structured problems in Chapter III and in relation to subquestion c of research question 3 contain further information that may guide thinking and research design with respect to these two types of problems.

Problem Reduction and Focusing

Problem reduction and focusing involves paying attention to some elements in or relevant to the problem situation and eliminating other elements from attentional focus. Although this process continues the problem identification function at a more specific level than was characteristic in problem representation, it sets the stage for the problem solving processes which follow it. The problem solver "carves out" of the total problem representation those aspects to be worked with in detail. This process is referred to in the problem solving literature as constructing a "problem space." Results of problem reduction and focusing include identification by the problem solver of key elements in current and desired states or conditions, cause-effect relationships related to these elements, the goal(s) to be reached, resources that are available or that could be developed, and means, tools or operators that might might be used in solving the problem.

Variables relevant to the problem reduction and focusing process and on which experts and novices might be compared include: the amount of time invested by the problem solver in reducing and focusing the problem; problem elements that do and do not receive attention; the sequence in which problem elements attended to receive attention; the amount of time allocated to attending to various problem elements; the type, content and amount of information that is sought and obtained by the problem solver in reducing and focusing the problem; the sequence in which information is sought and obtained; the sources from which information is sought and obtained; the methods by which information is sought and obtained; interpretations and evaluations applied to information obtained; allocation of time to seeking various kinds of information from various sources; bases for attention allocation and information-seeking; automaticity of attentional focus and information-seeking; ways and formats in which information is recorded (e.g., to what extent is an external memory, such as paper, used in holding and working with information? How is information organized in formats?); identification of problem space elements - key elements in present and desired states of affairs, cause-effect relationships present in problem situation, goal to be reached, resources available, and means, tools or operators with which problem can or must be solved; sequence in which problem space elements are identified, the explicit and implicit factors that are considered in their identification, and the relationship of the problem elements receiving attention and the information sought and obtained to the problem space elements identified; relationship between identified context, states, goals, resources and means.

Studies that incorporate only one or some of these variables are likely to be less useful than are more comprehensive studies because of the assumed interrelationships between the variables.

Problem reduction and focusing processes are particularly challenged by ill-structured problems which provide little information about present and desired states, cause-effect relationships, resources, and means for solving the problem. Problem reduction and focusing processes for such problems involve generation of these elements by the problem solver from whatever information is given, the problem solver's stored knowledge, and information sought out by the problem solver. Problem solvers also must reduce and focus well-structured problems which involves more emphasis on careful and accurate encoding, and strategic selection, organization and categorization of information already given in the problem and less emphasis on generation of new information. Ill-structured problems may provide especially useful opportunities for research focused on understanding problem reduction and focusing processes. Studies of experts and novices should be done using both kinds of problems so that the differences in what is required by each type of problem can be better understood.

Problem Solving Method Selection

Problem solving method selection has to do with the selection of an approach or approaches for generating potential problem solutions. The method selection process is solution-focused rather than problem-identification focused.

Problem solving methods have been identified (Newell & Simon, 1972) that provide a structure for interpreting data concerning strategies the problem solver uses in order to arrive at an effective and acceptable solution to a represented, reduced and focused problem. These problem solving methods, identified in Chapter III, include using an algorithm (recognizing a problem as a particular type and matching it with a clearly established method known to consistently yield an appropriate solution), generating all possible solutions and testing each, and finding a solution path. Newell and Simon discuss several subcategories within the solution path method including means-end analysis (identifying subgoals and means that achieve them), working forward (starting with the current state and specifying the features of the desired state so solutions that achieve these can be recognized), working backward (starting with the desired state and trying to construct states that precede it in order to trace a solution path) and planning (abstracting the problem in general terms, working out a solution, and then applying the abstracted solution in the actual problem). An additional method is to change the problem representation and then use any of these problem solving methods within a new representation. This method involves going back through the problem reduction and focusing processes to identify a different problem space and may also involve going back through problem representation to identify a different problem or re-categorize the selected problem.

Variables relevant to the problem solving methods selection process and on which novices and experts can be compared include: The amount of time invested by the problem solver in selecting a method for solving the problem; problem elements that do and do not receive attention; the sequence in which problem elements attended to receive attention; the amount of time allocated to attending to various problem elements; the type, content and amount of information that is sought and obtained by the problem solver in selecting a problem solving method; the sequence in which information is sought and obtained; the sources from which information is sought and obtained; the methods by which information is sought and obtained; interpretations and evaluations applied to information obtained; allocation of time to seeking various kinds of information from various sources; bases for attention allocation and information-seeking; automaticity of attentional focus and information-seeking; ways and formats in which information is recorded (e.g., to what extent is an external memory, such as paper, used in holding and working with information? How is information organized in formats?); problem solving methods considered and methods ignored, the sequence in which methods are considered, and the relationship of the problem elements receiving attention and the information sought and obtained to methods considered; problem solving methods selected, the sequence of selection, and factors considered in selection; and the effectiveness of methods selected in generating effective and acceptable solutions.

Studies that incorporate only one or some of these variables are likely to be considerably less useful than are more comprehensive studies because of the assumed interrelationships between the variables.

The study of problem solving method selection should incorporate both well and ill-structured problems since different methods may be more plausible in each of these types of problems. When fidelity (correspondence of the simulation to the acutal situation) of the problem used in the research process to problems in the real world is of major concern (and it usually will be a concern, particularly with respect to validity of research findings), decisions about the amount of structure in the research study problem may be best guided by the amount of structure in the real world problem of interest.

Solution Generation and Evaluation

The solution generation and evaluation process is closely tied to selection of a problem solving method. For example, a generate and test method requires generation of all possible solutions and testing each. In this method, key factors influencing its effectiveness in generating a solution that will solve the problem is the degree to which all possible solutions are generated and accurate testing of generated solutions occurs. Whatever method is chosen by the problem solver, the thoroughness and accuracy of its application in generating solutions will be an important factor. Consequently, problem solution and evaluation processes and their results should be studied in relation to problem solving method selection.

Variables relevant to the solution generation and evaluation process include: The amount of time invested by the problem solver in generating and testing solutions; solutions generated and evaluated, the sequence in which they are generated, and the factors considered in their generation and evaluation; sequence of attentional focus preceding and following solution generation and evaluation; amount of time allocated to elements preceding and following solution generation and evaluation; types, content, amount, and sequence of information that is sought preceding and following solution generation and evaluation; bases for attention allocation and information-seeking; automaticity of attentional focus and information-seeking; ways and formats in which information is recorded (e.g., to what extent is an external memory, such as paper, used in holding and working with information? How is information organized in formats?); interpretations and evaluations applied to solution test results; number of solutions generated; number and proportion of generated solutions evaluated as effective (i.e., produces the desired state or conditions) but unacceptable (does not fit resource or other constraints, produces undesired side effects, or is inappropriate for context) and as effective and acceptable (e.g., fits resource and other constraints, does not produce undesired side effects, is appropriate for the context, etc.); degree to which solutions generated represent different types of solutions or variations of the same type; degree of creativity expressed in generated solutions (see characteristics of creative products in Chapter II); and accuracy of solution effectiveness evaluation.

Studies that incorporate only one or some of these variables will be useful as will studies of broader scope and complexity which incorporate more of the variables.

Research Methods for Studying Problem Identification and Problem Solving Processes

Methods for collecting data concerning problem representation, reduction and focusing, problem solving method selection, and solution generation and evaluation include protocols, and the process tracing method identified and used by Elstein, Shulman and Sprafka (1978) combined with stimulated recall. Process tracing allows investigation of the sequential character of information-seeking leading up to judgments or decisions. Forms of simulation are used to represent the task environment. Process tracing can be done on data collected from situations arranged for through any of the following approaches: real problems in the actual setting, simulations involving role plays and contrived environments and situations, in-basket situations, and tab item formats. These are listed in descending order with respect to the potential fidelity they are likely to possess. The time and effort required for development of the situation and materials also varies in descending order from most to least. In identifying and developing simulations, fidelity, or correspondence between the simulation and the actual situation, is a variable that should be considered. The higher the fidelity, the more confident one can be that the problem solving processes observed in the simulation will be similar to or the same as those that would be used by the problem solver in a real life situation. Some researchers contend that complete simulation in a laboratory of the complexities of real life situations is almost impossible and have conducted their studies in work, home and other real life settings (Scribner, 1984; Rogoff & Lave, 1984).

Protocols developed by the researcher from direct observation of the problem solver and/or from recordings of the problem solver's "thinking aloud" are a frequently used method of collecting data in the role play and contrived environment and situations method. Verbal protocols can be used with the in-basket, and tab item methods which also produce other types of records of the problem solver's activity and thinking (Elstein, Shulman & Sprafka, 1978; Glaser, Damrin & Gardner, 1954).

The stimulated recall technique is needed for eliciting definitive information about the bases for attention allocation and information-seeking patterns, the degree of automaticity variable, and reasons behind the factors considered by the problem solver. To some extent, information about these may be directly provided in protocols and may be inferred from data that is provided but data in a protocol relative to these variables is likely to be incomplete. A source for help in judging the benefits and risks of incorporation of stimulated recall and for minimizing its validity risks is Ericsson and Simon (1984).

Dispositions

Dispositions identified as significant in human competence (e.g., motivations, interest, values, priorities, etc.) should be investigated in relation to stored knowledge, knowledge acquisition processes, and problem identificiation and problem solving processes in order to understand as comprehensively as possible what guides, organizes and forms effective actions regarding problems and in contexts central in vocational education. The problem solving literature has tended to focus less on dispositions that are functional in problem solving than on problem identification and problem solving processes. Investigation of dispositions is one approach to accounting for individual differences in stored knowledge, knowledge acquisition processes, and problem identification and solving processes. Variables that will be taken as dispositions in this inquiry agenda include: learning/information processing/cognitive style; flexibility and rigidity in problem representation, focusing, method selection and solution generation across varied problems; enduring interests and motivations and attentional biases; momentary intentions, interests and motivations; and self-awareness.

Learning style has to do with individual differences in the way information is acquired, processed and assimilated. Studies of cognitively-based learning styles suggest that learning style may reflect enduring dispositions regarding allocation of attention and information processing. As indicated in Chapter III, learning style studies suggest that individuals tend to place themselves in and seek out situations and tasks which will allow them to use their preferred modes of bringing new information into their cognitive structures. Through these mechanisms, learning style could also influence stored knowledge. It may be especially useful to control for learning style in attention allocation and information seeking-focused studies and in studies of problem solving processes. Investigations of potential relationships between learning style and characteristics of stored knowledge would also contribute to understanding of what role, if any, learning style plays in guiding, organizing and forming actions with respect to problems and contexts of central concern in vocational education. Kolb's learning style inventory (1981) and Gregorc's style delineator (1985) are possible measures of learning style that could be used in these studies. If the older concept of cognitive style is to be used, Goldstein and Blackman (1978) is a useful resource.

The degree to which an individual's skill in problem identification and problem solving transfer across different specific problems, across types of problems and across similar problems in different contexts is also worthy of investigation. The literature suggests that transfer may be very limited (e.g., Elstein, Shulman & Sprafka, 1978; Rogoff & Lave, 1984) and this has important implications for how expertise is viewed and developed. The question of transfer can be studied using designs and variables already suggested in connection with research question 2. The Elstein, Shulman and Sprafka (1978) study is a detailed example of research design which yielded data bearing directly on the question of transfer. Study of the degree of flexibility or rigidity evident in the problem representation, reduction and focusing, problem solving method selection and solution generation processes of problem solvers confronted with different kinds of problems may be useful in understanding individual differences in transfer and adaptation of problem identification and problem solving skills.

Enduring interests and motivations and attentional biases concern consistent patterns of an individual's interests, motivations and attentional biases across time and situations. These might involve the characteristics of creative persons discussed in Chapter II, or dispositions identified with critical thinking (Ennis, 1985). A challenge that will need to be met in including this variable in research studies is that of identifying or developing valid measures of these dispositions.

Momentary intentions, interest and motivations have to do with the intentions, interests and motivations of the problem solver in a particular situation or at a particular time. These factors would be anticipated to account to some extent for variation in an individual's actions from one situation to the next and from one moment to the next. The stimulated recall technique may be useful in providing data about such momentary dispositions.

Self-awareness of one's own stored knowedge, knowledge acquisition processes, problem identification and problem solving processes has been identified as an important feature of strategic knowledge, executive skills, or metacognition (e.g., Messick, 1984; Sternberg, 1985). This involves the ability to plan, direct, monitor and control one's actions. One variable self-awareness data may reveal is automaticity with respect to information processing (Anderson, 1980; Sternberg, 1985). Individuals who automatically process information are less likely to be able to describe their own processes than those who must consciously process information. Protocols combined with stimulated recall is an approach to obtaining self-awareness data.

Studies that address research question two are currently being done in various areas of psychology, education, in industry, and under military sponsorship. Some of these studies concern technical problems (e.g., Dillard, Bhaskar & Stephens, 1982; Gott, 1986; Lajoie, 1986; Logan & Eastman, 1986; Magone & Yengo, 1986). Others focus on managerial problems (e.g., Klemp, 1984). Still others are focused on more general understanding of human competence (Sternberg, 1985). If vocational educators wish to more thoroughly and precisely understand the knowledge, cognitive abilities and dispositions involved in competence concerning the problems and contexts central in the purposes of vocational education, the concepts and research tools for doing so are now available. Research efforts might be conducted jointly with cognitive psychologists and industry representatives.

In summary, the importance of research focused on research question two is that it will provide information useful in more precisely describing and more clearly understanding what is involved in competent functioning with respect to problems and contexts of concern in vocational education. This knowledge will provide a necessary basis for the design and evaluation of curriculum and instruction aimed at facilitating the development of stored knowledge, knowledge acquisition processes and problem identification and problem solving processes and for the development of assessment approaches for verifying this development. Research question three turns to the study of curricular design and instructional processes and their assessment.

Part III. Identifying, Developing and Assessing Curricular Designs and Instructional Processes that Facilitate Development of the Knowledge, Cognitive Abilities and Dispositions Required by Problems and Contexts Central in Vocational Education

Research Question 3: What curricular designs and instructional processes facilitate development of the stored knowledge, knowledge acquisition processes, and problem identification and problem solving processes that enhance ability to work with problems and in contexts of central concern in vocational education, and how can this learning be assessed?

The knowledge base resulting from research directed at research questions 1 and 2 will be an important foundation in the design of studies addressing research question 3. Knowledge resulting from work on research questions 1 and 2 is needed in order to know what knowledge, cognitive abilities and dispositions are needed, and for interpretation of assessment of student learning data.

Research question 3 focuses on what to teach and how to teach it in order to develop the identified knowledge, cognitive abilities and dispositions, and on how to determine if these have been learned.

While it is anticipated that extensive work on research question 3 will proceed best once some work addressing research questions 1 and 2 is completed, findings from more generally focused existing research applying cognitive science to curricular design and instructional processes might serve as a basis for some immediate work on research question 3. It should be noted, however, that instructional application-focused work is not yet as extensive as is the theory development work in cognitive science. Frederiksen (1984) points out that while there are many arguments for and ideas about the application of cognitive science to curriculum and instruction, there are relatively few studies that have investigated the validity of the arguments or the ideas in classroom settings. Rief (1980) also speaks to the need for research on what he calls prescriptive human information processing - ways of processing information that are specifically designed to improve human intellectual performance. Research proposed in connection with question 3 will reflect the current state of knowledge development by the inclusion of ideas and speculations as well as evidence. Assessment, in particular, is undeveloped. Pottinger and Goldsmith (1979) contains ideas and methods that may be useful for thinking about and developing assessment.

The instructional design literature is beginning to reflect a rapidly increasing number of studies focused on testing instructional designs that apply cognitive psychology findings (e.g., Champagne, Klopfer & Anderson, 1980; Chiesi, Spilich & Voss, 1979; Clement, 1982; Derry & Murphy, 1986; Dillard, Bhaskar and Stephens, 1982; Fredette & Lockhead, 1980; Gott, 1986; Hewson & Posner, 1984; Lajoie, 1986; Landa, 1974; Larkin, 1979; Lockhead & Clement, 1979; Logan & Eastman, 1986; Magone & Yengo, 1986; Mayer, 1975; Snow, Federico & Montague, 1980a, 1980b; Tennyson & Cocchiarella, 1986; Willems, 1981). A number of efforts in instructional design, some using expert tutoring systems have been focused specifically on technical training (Bonar & Logan, 1986; Lajoie, 1986; Magone & Yengo, 1986; McCombs, 1981-82) and provide potential models for instruction in some areas of vocational education. The studies included in this review are but a handful in relation to what will be produced in the next five years. Some of those future instruction-focused studies should include work done in vocational education.

Although the research agenda identified in this section is focused on curricular design, instructional process and assessment of learning, the educational setting is a factor that should be acknowledged. Educational efforts in vocational education take place in many different settings, including schools, businesses, agencies, etc. The priorities of the organization or institution in which educational processes are set influence what is learned and how it is learned. Since the learning of thinking processes takes time and goes beyond the storing of knowledge, emphasis within the educational setting on learners' scores on recall-oriented tests, for example, may discourage efforts on the part of instructors to teach beyond the recall level of learning. Further, it may not be possible to "cover the content" in the same way or in as short a time when the aim of instruction is the development of complex thinking processes as when the aim of instruction is knowledge storage for recall purposes.

An educational setting that provides staff development which builds the skills of educators in helping learners develop thinking skills is likely to facilitate the learning of thinking skills in students both through direct effects on teacher skills and through communicating to both teachers and learners that thinking skills are valued by allocating resources to their development. Teacher education programs that include development of thinking skills in their students as well as the ability to teach these skills also facilitate and support the development of thinking skills in the learners their graduates will serve. It would be anticipated that the most effective curriculum designs and instructional processes for helping learners develop the knowledge characterisitcs, cognitive abilities and dispositions identified in connection with research question 2 will be of limited influence on learning in an educational setting where the abilities to think and identify and solve problems are not valued.

The research and theory presented in Chapter III is having an impact throughout education. This impact is reflected in an increasing concern about curriculum designs that emphasize declarative knowledge and omit or fail to connect this knowledge with the processes and contexts to which it is relevant (Willems, 1981) and in debates that concern whether or not thinking processes are better taught as a separate curriculum, whether they are better integrated with existing curriculum, or if both approaches are needed (Quinby, 1985). Developments in cognitive psychology (e.g., Anderson, 1980, 1981, 1983) suggest that education needs to help students develop a cognitive structure that integrates declarative knowledge, thinking processes and affective elements. What types of curricular designs and instructional processes are needed to accomplish this integrated cognitive structure is a question research can help to answer.

Quellmalz (1985) suggests that curricular design be based on identification of thinking skills most central to a problem and knowledge domain through tracking where thinking skills seem to be required for addressing significant, recurring problem types and tasks in a knowledge domain. Likewise, Greeno (1980a) recommends analysis of a class of problems to determine the knowledge required and then teaching that knowledge. It is important to note that these approaches focus on recurring problem types and tasks and on problems sufficiently familiar to know, or at least determine, what knowledge is needed to be able to competently work with them. It has been speculated that teaching a knowledge base for the ill-structured problems that arise in real life may most functionally be approached by providing broad experience and general knowledge because ill-structured problems are essentially unfamiliar problems, problems about which little is known. Their nature cannot be predicted nor can the content of the knowledge base they require be specified (Frederiksen, 1984). Rapid social and technological change suggest the continual and rapid emergence of new, unfamiliar problems. It will be important in curricular and instructional design to be alert to the need to educate students to work with both known and emerging problems. The knowledge base for developing curricular designs and instructional processes for helping students learn to work with well-structured problems exceeds that for ill-structured problems. "More research on solving ill-structured problems in life-like situations might result in a better understanding of the processes involved in productive thinking and, ultimately, better instructional procedures" Frederiksen (1984, p. 391). This need underscores the importance of including ill-structured problems in research on question 2.

Part III of the research agenda is divided into three subquestions, each focusing on one of the three dimensions of competence identified with research question 2. The discussion of each subquestion begins with a brief description of the competence dimension followed by a summary of what is already known or hypothesized regarding what should be learned to develop the competence dimension, ways of facilitating that learning (to the extent these have been identified), and ways of assessing the effectiveness of curricular and instructional designs.

Subquestion a: What curricular designs and instructional processes facilitate development of stored knowledge characteristics that enhance ability to work with problems and contexts central in vocational education, and how can this learning be assessed?

The stored knowledge variables of concern are those identified with research question 2, subquestion a: Content, amount, arrangement, complexity and integration. Specific parameters of each of these associated with novice and expert levels of competence will be determined through research on question 2. The task for subquestion a of research question 3 is to determine how these characteristics can be developed and assessed.

Increasing Knowledge Retention

Retention of stored knowledge is concerned at the most basic level, with what and how much knowledge is retained in memory. Content of stored knowedge refers to the labels, facts, concepts, generalizations, schemas, scripts, processes, etc. a person has stored in their memory. Amount refers to the quantity of knowledge relevant to a problem or context that an individual has stored. Findings from information processing studies suggest several curricular design and instructional process strategies that have or are likely to have an impact on these two stored knowledge characteristics.

For example, research has indicated that when the learner has an opportunity to process thoroughly what is to be learned, storage and retention of knowledge is improved. Thorough processing entails sustained attentional focus on what is to be learned. Ways of bringing about this "deep processing" are reported in Anderson (1980) and suggested by findings reported by other information processing researchers (e.g., Lachman, Lachman, & Butterfield, 1979):

1. having the learner generate their own examples, ideas, and materials or continuation of some material rather than simply giving learners information.

2. having learners generate their own questions about the material they are learning (as opposed to having them answer questions generated by the teacher).

3. asking learners to consider some affective dimension of a concept (e.g., pleasantness, fears, etc.)

4. spacing encounters with material to be learned over time rather than dealing with it only once.

5. giving short quizzes throughout a learning sequence that cover all previously taught material rather than giving only one major test at the end or giving short quizzes that only cover the most recently taught material.

6. engaging several of the learner's sensory systems during the learning process rather than only one.

It would seem that whatever educators can do to engage and sustain the attentional focus of students on what is to be learned is likely to facilitate retention of the material in memory. One example of a strategy often used by educators for this purpose is motivating student interest in the material to be learned.

Try outs of instructional approaches incorporating problem solving by one of the authors indicated that when less relevant and more peripheral concepts were taught along with central concepts in the introductory stages of learning technical content that was new to college students enrolled in a vocational teacher education program, the less central concepts appeared to deter rather than enhance students' acquisition of the central concepts. An explanation for this is provided by information processing research which indicates reduction in retention of target information when irrelevant information is presented along with the target information. It is believed that the irrelevant information creates interference in the encoding (entry into the cognitive structure), processing and storage of the target information (Anderson, 1980). The phenomenon could also be explained from the standpoint of attention allocation. Attention would have to be spread over a larger array of information when irrelevant information is presented along with relevant information.

Concept learning is central to assuring that learners have a basic knowledge of concepts central in a field. Concept learning is a process of abstracting a general idea from first hand, sensory experience with several concrete examples that all possess the attributes of the concept (Tyson & Carroll, 1970). Shaw and Wilson (1976) recommend that, in addition to facts and principles, the core concepts in a field be taught through first- hand experience with varied exemplary instances of them (rather than second-hand hearing about them), preferrably through laboratory and field experiences. Such first-hand experience is believed to promote transfer of conceptual knowledge from one situation to another, including unfamiliar situations, because of the abstractions it is thought to develop. Joyce and Weil's (1980) concept attainment model is a teaching approach for concept development. Tyson and Carroll (1970) also provide instructional design guidelines for concept formation.

Studies should be done that apply these findings in vocational education curricular designs and instructional processes and evaluate the impact on learners' retention of what is learned.

Studies have shown that, not only is the substance of content stored in memory, but it is stored in relation to the context in which it was learned

(Lachman, Lachman, & Butterfield, 1979). Studies have revealed that only parts of the encoding context need be present for retrieval of stored knowledge to occur (Anderson, 1980). Context codes, stored along with the knowledge, are a factor in determining how and when the knowledge is recalled. Context is a means of making learning meaningful. Use of context as an instructional design strategy has been shown to have positive effects on learning (Anderson, 1980; Mayer, 1975; Messick, 1984). The importance of the context to learning and later usability of knowledge suggests that the contexts for which learning is relevant should be incorporated in and made explicit in the learning process (Willems, 1981). Ways of incorporating the context in the instructional process include:

1. asking learners to think about implications of what they are learning and the meaning of it to various individuals and in various situations (Anderson, 1980).

2. asking learners to visualize or imagine materials, situations, implications, etc. in connection with material they are learning (Anderson, 1980).

3. having learners construct a story or description involving a concept, process or principle (Anderson, 1980).

4. using teacher-generated questions that require processing a general issue rather than verbatim questions which require recall of a specific fact (Anderson, 1980).

5. use of functional context curricular designs (Brown, 1970).

6. explicitly teaching the links between information required by a situation and the cue(s) that the situation may provide (Willems, 1981).

When the learning goal is transfer and activation of stored knowledge in many different ways, spaced encounters with the material in different contexts has been shown to be effective. The critical features of each context should be noted in the learning process. When the learning goal is expertise in a single context, spaced encounters with the material in that context only is more effective than spaced encounters in varying contexts (Anderson, 1980). Experiments that apply these findings in vocational education to improve learning transfer across contexts and level of expertise development within a context are needed.

The degree to which intended contexts of application and contexts of learning are reflected and explicitly included in both curricular documents and in instruction should be examined. Experiments should compare in- context and across-context recall following learning situations where no context of intended application for what is to be learned was incorporated, where only one such context was incorporated, and where more than one application context was incorporated. The contexts identified in connection with research question 1 should be central in this research. A curricular analysis and development approach developed by Thomas (1985) is one way of approaching the development of curriculum for inclusion of context.

Methods that can be used for assessing the impact of these suggested curricular designs and instructional processes on content and amount of stored knowledge include those mentioned in connection with the study of the content and amount of experts' and novices' stored knowledge in subquestion a of research question 2. These methodologies included information processing research techniques such as recall exercises after presentation of situations or materials (Anderson, 1980; Lachman, Lachman & Butterfield, 1979) and analysis of concept maps and flow charts developed by learners (see pages 35-36 for a description of these approaches) for content and quantity of knowledge reflected.

Facilitating Functional Arrangements of Stored Knowledge

Arrangement of stored knowledge refers to the clusters and groupings of stored knowledge, i.e., which concepts are stored together in what kinds of relationships, such as hierarchical, sequential, condition-action, cause-effect, etc. Also of interest are arrangements in which context is stored with concepts. The arrangement of stored knowledge, as indicated in Chapter III, influences what knowledge will be available when the individual accesses any piece of their stored knowledge and how new information will be perceived, interpreted, and stored. The information processing and problem solving literature suggests that curricular designs and instructional processes which facilitate the development of hierarchical arrangements (Frederiksen, 1984), condition-action units (Larkin, 1979), and problem-related schemas and scripts that facilitate pattern recognition in problems (Frederiksen, 1984) are particularly likely to enhance problem solving competence. Designs and processes that facilitate context-concept clusters and condition-action units are likely to enhance transfer and usability of knowledge as already indicated in the previous section.

The way knowledge is structured, presented and experienced in the learning situation appears to influence the arrangements in which it is stored in learners' cognitive structures (e.g., Tennyson & Cocchiarella, 1986; West & Pines, 1985). Try outs of approaches for eliciting stored knowledge structures of students enrolled in a course taught by one of the authors were supportive of this finding. Structures in which knowledge was stored in memory changed over the course of ten weeks of instruction. At the end of instruction knowledge structures were more hierarchical and reflected the course outline and the instructional sequence.

Ways of facilitating certain knowledge arrangements through curricular design and instructional processes include (Anderson, 1980; Larkin, 1979; Novak & Gowin, 1984; Posner & Rudnitsky, 1982; Tennyson & Cocchiarella, 1986): 1) careful attention to the structure of course outlines so that they reflect desired arrangements, and then sharing these with learners; 2) providing advance organizers such as questions or summary statements of what material to be read is about before reading; 3) using hierarchical, condition-action, context-concept, and problem-related schema and script organizations when presenting material and simultaneously sharing visual pictures of these knowledge arrangements in the form of outlines, concept maps, flow charts or other types of charts or diagrams; and 4) asking learners to draw their own concept maps, flow charts, hierarchical organizations or other knowledge arrangement diagrams.

Other curricular design and instructional process strategies suggested in the literature as likely to develop functional stored knowledge arrangements for expertise in problem solving and other types of higher order thinking processes include:

1) Introduction of a problem and then having students relate the content to be learned to the problem. This approach appears to enable learners to store knowledge in a way that links the knowledge to its relevant use in working with problems (Bransford, 1986).

2) Techniques discussed in connection with context in the previous section on developing content and amount of stored knowledge would be relevant for incorporating concept-context arrangements into curricular designs and instructional processes.

3) Concept development strategies that have been recommended for some time in educational practice (e.g., Joyce & Weil, 1980; Tyson & Carroll, 1970) are likely to be useful in developing concept-focused schemas and scripts. The information processing literature suggests that it is useful to build nodes (major intersections in a knowledge structure) in concept schemas at the functional level (Lachman, Lachman & Butterfield, 1979). For example, "building exterior protective materials" might be taught as a central concept (node) with shakes, wood overlap siding, aluminum siding, stucco, etc. taught as instances that fulfill the function in various situations and under various conditions. The usefulness of a functional level-based knowledge structure for knowledge transfer, adaptability, and problem solving is intuitively apparent. Instances are likely to change more frequently with time and over contexts than are functions. Learning of new instances is likely to be more efficient when stored knowledge is structured in a way that can readily accommodate them.

4) Teaching cues in a situation, connecting them to functional elements relevant in the situation (e.g., teaching the functional elements in schematics of electronic circuits, Egan & Schwarz, 1979), and providing extensive practice in recognizing them (Gregg, 1974). Patterns of cues, called schemas (Frederiksen, 1984), can be taught in this manner.

In general, educational strategies for developing knowledge arrangements are likely to enhance the formation of networks of stored knowledge, elaborate meaning of knowledge being learned, and enhance its retention and potential for re-activation when it is relevant.

Alternative curricular conceptual structures should be tested with respect to their impact on the arrangements in which learners store the knowledge learned. Some examples of alternative principles for structuring curricular content are provided in Table 2.

Methods that could be used to assess the impact of curricular designs and instructional processes on the arrangement of learners' stored knowledge include pre- and post-instructional and experimental-control group comparisons of: learner developed concept maps (Novak & Gowin, 1984; Posner & Rudnitsky, 1982); flow charts (Posner & Rudnitsky, 1982); techniques described by Sternberg (1985), especially in connection with his work on assessing social and practical

Table 2. Examples of alternative ways of structuring curricular content.

Structuring Principle	Examples
Content-based	Structure of the content
	-concrete to abstract
	-general to specific
	-specific to general
	-simple to complex
	-conceptual similarity or relatedness
	-logical prerequisites
	-attributes of concepts
	-basic ideas and principles to refinements
	-general survey to special problems
	Sequence of a process
	-procedural order
	-most frequently used components to least used
	-components done together
	-similar operations
	-skill prerequisites
Chronological sequence	Time
	Developmental
Learner-based	Problem occurrence in learners' experience
	Issues learners are confronting
	Familiar to unfamiliar
	Most to least interesting
	Least to more difficult
	Internalization: focus on others, then self
	Less to more responsibility
Instructional design-based	Project prerequisites
	Simulation prerequisites
	Field experiences prerequisites
	Requirements of problems learners will experience
	-condition-action units
	-schemas and scripts

intelligence; techniques reported by information processing researchers including ways of identifying stored prototypic examples (i.e., generic examples that represent in a person's mind an entire category), feature weights (i.e., perceived centrality of various features to a concept), and schemas and scripts (e.g., Anderson, 1980; Lachman, Lachman & Butterfield, 1979). Specific examples of information processing-oriented assessment approaches include test items that ask about relationships between concepts such as word association tests, asking students to judge the strength of relationships between concepts that are presented in pairs (Frederiksen, 1984) and presenting a situation to learners that contains cues and then asking learners to write as much of the situation as they can remember (Norman, Jacoby, Geightner, & Campbell, 1979; Wortman, 1972). These and other similar techniques have been used with promising results by the senior author as a basis for developing assessment designs for home economics curriculum. Further assessment techniques are described and illustrated in West and Pines (1985).

Increasing Complexity of Stored Knowledge

Complexity refers to the number of levels in which knowledge is stored. For example, in hierarchical arrangements of stored knowledge, more general, abstract levels are stored in relation to several more specific levels. Individuals having many levels represented in their stored knowledge are likely to have a knowledge structure that ranges from very concrete, specific bits of information to very abstract concepts. Less research was identified that provided specific models or recommendations for affecting complexity of stored knowledge compared with that relevant to affecting content, amount and arrangement of stored knowledge. Although there is considerable speculation in the literature regarding the value of specific versus general knowledge (Frederiksen, 1984), the judgment of many experts is that knowledge specific to a domain or class of problems is needed in order to possess expertise in solving problems and functioning capably in other ways within the domain (Greeno, 1980b; Messick, 1984; Norman, 1980). Perhaps an even more useful view is Reif's (1980) which does not take an either/or position, but rather, suggests that if knowledge is structured in hierarchies that range from the highly abstract and general to the very specific and local, the learner will possess the prerequisites for expertise in a specific domain of knowledge and problems but will also have what is needed to make the knowledge flexible and transferable and useful in dealing with unknown, unfamiliar ill-structured problems.

Structuring conceptual content in hierarchies, as already suggested in connection with knowledge arrangement, and sharing these with students would seem to be one way to facilitate the development of multiple levels in stored knowledge structures. Evidence suggests that arranging such hierarchies so that broad, general functional properties are at higher, more abstract levels, and structural, surface properties are at lower levels may be useful (Chase & Chi, 1980). There is some argument in the literature about whether more didactic, rule-giving or explaining teaching approaches are as useful as more experientially-based ones in teaching for higher level knowledge structures (Frederiksen, 1984; Willems, 1981). Use of Piagetian-based or other learning cycles described by Kolb (1984) and reflected in work by Perry (1970) and Chickering (1977) is an educational approach that includes both experience and explicit approaches for helping students connect abstract ideas with their concrete experience and relate "local values" or specific instances to more general cues and functions. Studies of experts and novices that suggest that the number of levels in which knowledge is stored increases with experience imply that providing students with many and different experiences with a concept or procedure might expand the number of levels in their stored knowledge structure. Helping learners to think about their experiences and abstract more general ideas and patterns from them would be an important element in assuring that the experiences contribute to developing more abstract levels of stored knowledge. Having students create their own outlines and concept maps may be useful in this process. A number of instructional approaches likely to affect complexity of stored knowledge are illustrated in West and Pines (1985).

Increasing Integration of Stored Knowledge

Degree of integration refers to the extent to which large clusters and groupings of stored knowledge are linked together, particularly, the extent to which declarative and procedural knowledge are interwoven (Anderson, 1980; Messick, 1984) and linked to strategic knowledge and affect. The information processing and problem solving literature suggests that curricular designs and instructional processes which facilitate the development of integrated stored knowledge structures are likely to enhance competence (Frederiksen, 1984; Willems, 1981).

Like the complexity characteristic, less research was uncovered that provided specific models or recommendations for affecting integration of stored knowledge. Explicitly teaching declarative, procedural and strategic knowledge and their connections has been suggested as one way to bring about integration of stored knowledge (e.g., Willems, 1981). The extent to which these types of knowledge are taught concurrently would also seem to influence integration, given that knowledge storage is closely linked to the situation in which it was learned.

Tennyson and Cocchiarella's research review (1986) and West and Pines (1985) provide detailed and useful summaries of instructional designs and methodologies with respect to concept learning and also discuss the role of procedural learning in concept rentention and ways of bringing procedural learning about. Structuring curricular designs and instructional processes in terms of condition-action units which teach the function of the knowledge along with the knowledge (Larkin, 1979), already mentioned in connection with affecting arrangement of stored knowledge, would seem to be another way of facilitating integration of declarative and procedural knowledge. Condition-action units have been described as enabling a special type of pattern recognition in which situational cues are recognized and signal appropriate actions (Simon, 1980). A study by Egan and Greeno (1973) indicated that discovery learning was more effective than teaching rules in developing a well-integrated cognitive structure. Research is needed to test these and other approaches to facilitating development of an integrated stored knowledge structure.

Pre- and post-instruction development of concept maps and flow charts by students and analysis and comparison of these in experimental and control conditions for the number of levels represented in the map (to assess complexity of stored knowledge) and the number of cross-links included (to assess degree of integration) is one approach to assessment. Novak and Gowin (1984) provide detailed procedures for both qualitative and quantitative analyses of concept maps in relation to complexity and integration of the knowledge structure. Concept maps and flow charts allow observation of all five of the stored knowledge characteristics including content and quantity, the way it is arranged, the number of levels it represents and the degree of integration. The technique involves having the individual draw a "map" or diagram of a concept or process and then analyzing the map or diagram for its content and structure. Use of concept maps by the senior author for observing changes in the content and structure of stored knowledge before and after instruction has indicated that such maps do reveal changes in all of these characteristics of stored knowledge.

Concept maps can also be used to help learners develop metacognitive awareness of the characteristics of their own stored knowledge. As discussed in earlier chapters, metacognition is awareness of one's own cognitive processes and patterns. Concept mapping and flow charting is a tool for developing such awareness because it represents a "picture" of the learner's own knowledge and allows the learner to analyze and refine their own knowledge structures. Novak and Gowin (1984) also recommend their vee heuristic as another approach for increasing metacognitive awareness.

Learning style is a variable that should be included as a control or independent variable in selected investigations related to curricular design and instructional process. This recommendation is based on the evidence that suggests that different students learn better in some learning situations than others (Kolb, 1976, 1984; Gregorc, 1979) and may store information in different patterns (Gregorc, 1979). Incorporating the same learning goals and content in different curricular designs and instructional processes that are based on differences in the ways people have been found to learn and testing these designs and processes for their effectiveness in affecting characteristics of stored knowledge of learners with different learning styles would provide information helpful in guiding instructional design. Ways of measuring learning style include the Kolb Learning Style Inventory (1981) and Gregorc's Style Delineator (1985).

Subquestion b: What curricular designs and instructional processes facilitate development of knowledge acquisition processes that enhance ability to work with problems and contexts central in vocational education, and how can this learning be assessed?

Subquestion b concerns teaching the learner ways of directing their perceptual, attention focusing resources and information-seeking efforts that are functional for various knowledge acquisition goals.

Facilitating development of attentional focus

Helping learners know how to focus their attention in situations and problems is a task of curricular designs and instructional processes of interest in subquestion b. The teaching of attentional focus will entail helping learners focus their attention in a problem or other type of situation on cues that are relevant to their goal(s) and providing learners with sufficient practice so that functional attention focusing patterns become automatic. Learners' goals may include understanding a situation, or affecting it or themselves in relation to it in some way. Attentional focus has been identified as an important function in both learning situations and problem solving situations (Anderson, 1980; Sternberg, 1985). There is a close relationship between helping learners to develop functional attentional focus patterns as a knowledge acquisition skill and developing learners' stored knowledge in ways that link contexts, cues and actions.

Techniques for influencing the attentional focus of learners have already been mentioned in connection with enhancing storage of knowledge (e.g., providing learners with advance organizers, introducing a problem and then having students relate the content to be learned to the problem). The difference between those techniques and developing attentional focus patterns as a knowledge acquisition skill is in who controls the learner's attentional focus. In the stored knowledge discussion, learners' attentional focus was controlled by the instructor. The focus of the present discussion is on helping learners learn to control and direct their own attentional focus so that they can operate more independently in problem and other kinds of situations.

Curricular designs and instructional processes for helping students learn to strategically control their own attentional focusing in learning and problem solving situations relevant to vocational education need to be developed and tested. One example of a strategy intended to teach attention focusing patterns in reading new material is the PQR4 method, and a variation, the SQR4 method (Anderson, 1980, p. 218). The acronyms are a mnemonic (memory assisting) device to help learners remember an attentional focus and procedural sequence: P or S - Preview or Scan, Q - Question (develop questions to be answered in reading the material), R_1 - Read (try to answer the questions), R_2 - Reflect (understand, relate to prior knowledge), R_3 - Recite (recall the information read, the answers to the questions), R_4 - Review (recall main points; re-answer the questions). The PQR4 and SQR4 method might be viewed as an attentional focus algorithm for reading. An algorithm is a rule or procedure guaranteed to yield a particular result. The PQR4/SQR4 method guides the object of attentional focus (what attention is focused upon), the sequence in which attention is focused, and the goals for each type of attentional focus.

Resnick (1976) and Glaser (1976b) suggest that independence-facilitating, attention-related "learning to learn" skills involve a feature detection skill in which an environment is systematically scanned for appropriate cues. The concept of cues is likely to be helpful in considering how the teaching of attentional focus might be approached. Helping students know what cues in a problem situation are likely to be most informative and to reflect symptoms of a problem and then helping them identify these cues and their patterns in actual situations is one way of approaching the education of attentional focus. Functional algorithms identified through research on question 2 or specifically developed for instructional purposes could help learners allocate their own attentional resources more effectively in acquiring knowledge. Students also need to be able to discern when the algorithms they have learned should be applied and when new patterns of attentional focusing are needed. Further, students need to be taught to develop their own attentional focus algorithms as a strategy for dealing with situations and problems requiring new patterns of attentional focus.

Methods likely to be useful in assessing the impact of curricular designs and instructional processes on attentional focus patterns with respect to the object, length of time, sequence, and accuracy and extent of cue perception include a range of techniques used in information processing studies on attention and perception and reported in Lachman, Lachman and Butterfield (1979) and Anderson (1980), protocols (Dillard, Bhaskar & Stephens, 1982; Larkin, 1979), the tab-item technique (Glaser, Damrin & Gardner, 1954), the in-basket technique (Frederiksen, Saunder, & Wand, 1957), and additional techniques used to track the attentional focus of physicians in working on medical diagnosis problems and reported in detail in Elstein, Shulman, and Sprafka (1978). These techniques were described in connection with subquestion b of research question 2. Collection and comparison of pre- and post-instruction data for experimental and control learning situations should be possible using these techniques.

Facilitating development of information-seeking

Information-seeking concerns searching for and developing information relevant to some purpose with regard to a situation or problem. Information-seeking involves initiative on the part of the learner or problem solver to examine an aspect of a situation or problem or develop an information base relevant to some understanding-related or action-related goal. Information-seeking is a purposeful activity, the results of which expand the information available to the learner or problem solver. Educating learners regarding information-seeking is likely to involve helping them understand and determine the types and content of information relevant to a problem or situation, the amount of information needed and warranted, special sequences that might be especially useful in seeking information, the sources from which relevant information might be obtained (including their own memory), methods by which information might be obtained, alternative ways of recording and formating information for ease of processing and accuracy of interpretation, and approaches for and concepts relevant to interpreting and evaluating information. Curricular designs and instructional approaches for teaching these aspects of information-seeking as they relate to problems and contexts central in vocational education need to be developed and tested.

Curricular designs and instructional processes which reflect instructor-directed information-seeking on the part of learners and which have been shown to affect knowledge storage and arrangement have already been reported (e.g., asking questions that require investigation rather than verbatim questions which require recall of a specific fact; posing questions prior to reading). Already mentioned strategies likely to help learners operate more independently in problem and other kinds of situations by developing their own strategies for information-seeking include having learners generate their own questions, implications and meanings regarding material they are learning or problems they are solving, and teaching information-seeking algorithms. The PQR4/SQR4 strategy might be viewed as an information-seeking as well as an attentional focusing algorithm. While these approaches have been shown to be effective in enhancing learning of conceptual material, no studies were reviewed that examined their effectiveness in facilitating learning of information-seeking strategies and processes. Such studies could be conducted.

Problem solving studies have indicated that use of an external memory (e.g., paper) for recording and manipulating information may decrease the information processing load on the short term memory (the central information processor in the brain) and allow more information to be available to the problem solver than if the problem solver must rely entirely on what can be held at one time in the short term memory (Newell & Simon, 1972). These findings suggest that teaching ways of handling information which reduce the load on short term memory such as use of paper and pencil for recording and manipulating information and formating information in ways that make comparisons and other operations on it easier would contribute to learners' ability to use the information they obtain. Joyce and Weil's (1980) interpretation of data teaching model is a resource that would be helpful in the development of potential instructional designs.

An example of a model for determining warranted time investment in information-seeking in relation to consumer information-seeking problems is provided by Maynes (1974, 1976). Construction of similar models for other kinds of problems and contexts relevant in vocational education and development of decision rules (algorithms) from them that could be taught to students is one approach for increasing learners' ability to make judgments about the payoff of information-seeking time. An approach for teaching the Maynes' model has been developed (Thomas,1981).

General criteria upon which information obtained might be evaluated could also be taught. Many approaches for teaching this are suggested (Costa, 1985; Joyce & Weil, 1980; Metcalf, 1971) but few appear to have been subjected to rigorous systematic testing in the classroom.

The tab item and in-basket techniques, identified in connection with research question 2 and with assessment of learning in various components of this agenda, have potential for adaptation as teaching tools for helping learners develop and practice functional and strategic information-seeking patterns. Besides being particularly focused on information-seeking and interpretation, these two techniques would provide opportunities for self-analysis by learners of their own attentional focus and information-seeking patterns.

Techniques suited to assessing change in information-seeking patterns as a result of curricular designs and instructional processes include pre- and post-instruction participation by learners in protocol generation (Dillard, Bhaskar & Stephens, 1982; Larkin, 1979), tab item simulations (Glaser, Damrin & Gardner, 1954), in-basket simulations (Frederiksen, Saunders & Wand, 1957), and the twenty questions approach (Elstein, Shulman & Sprafka, 1978), and experimental-control comparisons of the data. All of these techniques allow analysis of the type, content, and amount of information sought and obtained, the sources from which information is sought and obtained, and the sequences of information-seeking leading up to judgments or decisions. They also have potential to provide opportunity to examine change in information recording approaches and formats. Protocols and stimulated recall techniques (described earlier) can be used to study change in learners' patterns of information interpretation and evaluation and change in their bases for information-seeking.

Search by the learner of their own memory for information is a type of information-seeking skill that is relevant to problem solving and other functions that involve combining what one knows already with new information.

Evidence suggests that open-ended, free response type test items are superior to reconition-type test items (e.g., multiple choice) for demonstrating skills in memory search (Frederiksen, 1984).

Studies suggest that learning style is related to enduring attentional biases and that individuals tend to place themselves in and seek out situations and tasks which will allow them to use their preferred modes of adding new information to their stored knowledge. Learning style should be incorporated as a control variable in selected studies examining the impact of curricular design and instructional processes on learners' attentional focus and information-seeking patterns. Such studies should have as a basic question, "What curricular designs and instructional processes develop functional attentional focusing and information seeking patterns in which learners?" Learners with different styles might be taught ways of capitalizing on the strengths of their style and minimizing the weaknesses, as well as ways of operating with other styles when the situation demands such adjustments. The effect of learner awareness of their own learning style and its impact on their attentional focus and information-seeking patterns on learners' ability to control and adjust their own enduring patterns should be studied.

Curricular designs and instructional processes might be developed to increase other enduring interests and motivations, priorities and values identified with creative persons (see Chapter II) and critical thinking (Ennis, 1985). Synectics (Joyce & Weil, 1980) and the jurisprudential teaching model (Joyce & Weil, 1980; Metcalf, 1971) are potential instructional approaches.

Subquestion c: What curricular designs and instructional processes facilitate development of problem identification and problem solving processes that enhance ability to work with problems and contexts central in vocational education, and how can this learning be assessed?

Little was revealed in the literature reviewed concerning tested curricular designs or instructional processes for teaching problem identification and problem solving processes. A statement by Frederiksen (1984) summarizes the state of knowledge regarding instruction in problem solving: " . . . we find more suggestions as to what processes should be taught than how to teach them." (p. 373). . . . it seems that the arguments for the educational objectives and instructional procedures that have been suggested by cognitive psychologists are persuasive, particularly in those areas involving development of problem representations, procedural knowledge, pattern recognition, and automatic processing. But, so far, there have been few investigations in classroom settings concerned with the application of cognitive theory to instruction . . . There is a need for a great deal of research on instruction in which ideas . . . are tried out and evaluated in educational settings . . . "(p. 398).

Selected references that bear on the application of cognitive science findings in curricular design and instructional processes include Anderson (1981), Costa (1985), Glaser (1978), Klahr (1976), Landa (1974), Laster (1985), Lesgold, Pellegrino, Fokkema, and Glaser (1977), Lockhead and Clement (1979), Rogoff and Lave (1984), Snow, Federico and Montague (1980a, 1980b), Tuma and Reif (1980), West and Pines (1985) and Willems (1981).

Educational Implications of the Varied Nature of Problems

One of the most basic questions that arises in considering how to approach the teaching of problem solving is that of what is considered to be problem solving activity. In the literature, activites as limited in scope as retrieving information stored in memory to those as complicated as predicting the future state of some aspect of society are referred to as problem solving activity. Results of research on questions 1 and 2 should be helpful in clarifying what, in vocational education, is appropriately considered problem solving activity.

Differences in the nature of problems have implications for what should and can be taught. Based on a review of cognitive psychology literature for the purpose of drawing instructional implications, Frederiksen (1984) states: "For well-structured problems in relatively narrow domains of knowledge, such as mathematics, there is no doubt that we do know how to teach specific skills . . . Presumably, we also know how to teach pattern recognition and automatic processing for problems of a sort that are encountered repeatedly as in reading . . . But as we go into domains where problems are increasingly ill-structured, we can be much less certain about the adequacy of our knowledge. We know little about how to teach students to develop representation of ill-structured problems, to develop plans for solving such problems, or to employ appropriate strategies or heuristic approaches. Still less can we advise students about efficient methods for accessing relevant information in (memory). Much needs to be learned about how ill-structured problems are solved." (p. 396).

A conclusion that arises from the problem solving literature is that the ill-structured, well-structured dichotomy is too general and simplistic a view of problem types to be useful as a basis for curricular design and instructional process. Frederiksen (1984, p. 376) suggests a three-category system including: 1) well-structured problems which are clearly formulated, have known algorithms for representing, focusing and reducing and solving them, and for which criteria are available for testing correctness of the solution; 2) ill-structured problems which lack a clear formulation, a procedure that guarantees a correct solution, and criteria for evaluating solutions; and 3) a middle category called "structured problems requiring productive thinking," which includes problems that resemble well-structured problems but for which the problem-solving procedure or some crucial step in the procedure must be generated by the problem solver. Frederiksen points out, as have others, that most current theories of problem solving are information-processing-theory-based and are concerned primarily with well-structured problems and problems requiring productive thinking. Problems that appear to be ill-structured have the potential to become well-structured if they appear repeatedly in forms that are sufficiently similar to permit the consistencies to be perceived and pattern-recognition skills to be developed. When problems lack such consistency, they must remain ill-structured and the problem solver must continue to use slow processes such as those that characterize the first stage of learning, aided by whatever relevant strategic or metacognitive skills have been acquired. (Frederiksen, 1984, pgs. 391-392).

Stages of learning problem identification and problem solving processes are described by Frederiksen (1984). At the beginner stage, problem solving is a slow and laborious task that requires close attention, frequent review of relevant information, and search of memory for relevant ideas, information and knowledge. As problem solvers gain experience with a problem, they develop appropriate, integrated, and well-organized knowledge structures, adequate representations of problems, automatic information processing, and efficient pattern recognition systems that trigger appropriate problem-solving procedures. (Anderson, 1980; Frederiksen, 1984).

Rather than categories of well-structured and ill-structured problems, a more differentiated categorization of problems that takes the particular situation and the problem solver as well as the problem into account seems warranted. Such a categorization is presented in Table 3. Three sources of problem structure are indicated by the three column headings at the top of the table: Existing knowledge, problem presentation, and the problem solver. Existing knowledge as a source of problem structure has to do with whether or not knowledge needed to identify and solve a problem exists relative to the problem in a generally available, disciplinary, professional or occupational knowledge system. Problem presentation as a source of problem structure concerns how much information is present in the problem situation. For example, a child may have a fever one day and two days later be covered with red spots. The red spot situation presents more information about the problem than did the fever-only situation. The problem solver as a source of problem structure concerns the amount of knowledge possessed by the problem solver that is relevant to a problem. Experts are a better source of problem structure than are novices.

By varying the amount of structure (amount of structure can be thought of as amount of information) present in each of the three sources with respect to any given problem, five conditions are possible. These five conditions are represented by the numbers, 1 through 5 in the left hand column of Table 3.

Table 3. Sources and conditions of problem structure

Problem Structure Conditions	Sources of Problem Structure		
	Existing Knowledge	Problem Presentation	Problem Solver
1	Lo	Lo	Lo
2	High	Lo	Lo
3	High	Lo	High
4	High	High	Lo
5	High	High	High

Problems characterized by condition 1 are genuinely ill-structured in every sense. Since very little knowledge about them is in existence, specific instances or presentations of such problems will be very vague, sketchy and incomplete, and problem solvers will possess little knowledge that they can relate to the problem. Problem solvers in this condition need practice in problem finding and formulation from the sketchy, vague and incomplete presentations that, of necessity, characterize these problems, as well as practice in developing attentional focusing and information generation strategies and procedures.

In condition 2, knowledge about the problem exists, but not very much of what exists is included in the particular presentation of the problem, nor is it possessed by the problem solver. Consequently, for the problem solver, the condition 2 type problem is as ill-structered as is the condition 1 problem. There is, however, more potential for the problem to become well-structured if the existing knowledge can be included in the problem presentation or if the problem solver can acquire the existing knowledge. Problem solvers in this condition need to learn the existing knowledge and to practice connecting the knowledge with sketchy, vague and incomplete problem presentations.

Condition 3 is like condition 2 in that knowledge needed to identify and solve the problem exists but is not included in the problem presentation. However, in this condition, the problem solver possesses the needed knowledge which enables the problem solver to add missing structure to the problem. Problem solvers in this condtion need practice in connecting the knowledge they already possess with sketchy, vague and incomplete problem presentations.

In condition 4, knowledge needed to identify and solve the problem exists and is provided in the problem presentation but the problem solver does not possess the knowledge and is therefore unable to effectively use the information provided in the problem presentation. Problem solvers in this condition need to learn the relevant knowledge required for recognizing and interpreting cues presented in problem situations and practice in using it for this purpose.

The fifth condition truly represents the well-structured problem where the knowledge needed to identify and solve the problem not only exists, it is provided in the problem presentation, and, in addition, the problem solver possesses the knowledge needed for recognizing and interpreting cues presented in problem situations.

This analysis of well- and ill-structured problems illustrates the complexities and variations that need to be considered in instructional designs focused on problem solving. It also illustrates a how a problem can move from being an ill-structured to a well-structured problem as existing knowledge is developed, incorporated in problem presentations and is learned by problem solvers. Further, it illustrates why truly ill-structured problems are so challenging to work with as a problem solver and in teaching others how to work with them. The presentation of the problem may be a major factor in what differentiates academic, school-type problems that students are "given," and which tend to specify needed information, from the problems students meet in the real world which tend to provide very little information.

Teaching and Learning Problem Solving

The degree to which problem solving can be taught explicitly (i.e., by carefully structuring the cognitive tasks and by directing learners through the problem-solving processes as a series of exercises with systematic guidance, practice opportunities and corrective feedback) depends on the amount of existing knowledge relevant to the problem (Frederiksen, 1984). Olson (1976) makes the point that unless algorithms underlying skills and knowledge are known, they cannot be taught explicitly. Other times when explicit instruction is not as applicable as experiential instruction approaches are when what is to be taught must be worked out by the individual learner (Frederiksen, 1984) and when higher level knowledge structures and processes are to be developed (Doyle, 1983; Frederiksen, 1984). This suggests that routine problem solving processes may be taught explicitly but that creative problem solving, for which algorithms are unknown and which involve the formation and use of higher level knowledge structures, needs to be taught using other approaches. Egan and Greeno (1973) found that discovery learning involving self-discovery of meaning and purpose and opportunities for learners to derive generalizations and procedures for themselves, was more effective than teaching rules in facilitating learners' reorganization of a problem space. Willems (1981) and Frederiksen (1984) suggest that discovery training might proceed by leaving gaps in a series of procedural steps that students must fill for themselves, and gradually introducing opportunities to construct larger parts of the problem-solving procedure. Explicit teaching of rules and procedures may be more appropriate for beginners in a problem area with experiential or discovery learning being used with advanced students (Frederiksen, 1984, Willems, 1981).

Two concepts arising from research in nonformal educational situations (Rogoff & Lave, 1984) that may be useful in developing the experientially-oriented instructional designs that a skill as complex as problem solving appears to require are scaffolding and propleptic teaching. Scaffolding is a technique in which the teacher selectively intervenes in the learner's work on a problem or task to provide a supportive tool for the learner, extending the learner's skills and allowing the learner to successfully accomplish a task not otherwise possible. Scaffolding by the teacher closes the gap between the task requirements and the skill level of the learner. While scaffolding resembles the concept of shaping from behavioral psychology, it differs in that the task is held constant and the learner's role through the task is simplified (Greenfield, 1984, pp. 118-119, 135). The teacher must determine the learner's "zone of proximal development" (Vgotsky, 1978) and build the scaffold accordingly. The zone of proximal development is the phase in the development of a cognitive skill where the learner has only partially mastered the skill but can successfully employ it and eventually internalize it with the assistance and supervision of an expert. Since this zone is continually moving as the learner develops, the teacher needs to follow it. The approach for teaching problem solving described by Willems (1981) is designed to do this but needs to be tested.

Propleptic instruction is an experiential approach to teaching, embedded in the particular problem situation rather than an explicit recipe for problem solution. Propleptic instruction is not teaching by explanation (teacher giving the rules and talking about the task) or by demonstration (teacher carries out the task without involving the learner in the action). It is instructing by teacher and learner(s) working together through a process or task in ways that the teacher's knowledge is transferred to the learner as the learner is guided by the teacher. It involves transfer of information and responsibility for managing joint problem solving from the instructor to the learner. In propleptic instruction, the learner is actually performing the task under expert guidance. The learner participates in creating the relevant contextual knowledge for the task and acquires some of the expert's understanding of the problem and its solution. The teacher is available to mark the crucial actions, provide guidance at choice points, and indicate important variations. Two primary principles of propleptic instruction are careful guidance and graduated participation (Greenfield, 1984; Rogoff & Gardner, 1984).

Developmental studies of problem solvers would serve the need educators have to understand the stages through which ability to work with problems develops in order to direct educational designs to the learners' stage of development. Studies that simply compare novices with experts may not provide enough information about intermediate levels of development to sufficiently help educators in the educational design process. Concurrent research designs could be used in which people at varying stages along a continuum of development, experience, and expertise are identified and compared with respect to selected variables identified in Appendix A. The challenge in such studies will be accurately determining the stage of development a person represents. Longitudinal designs could also be used which would look at the same people over time as they gained experience and developed their knowledge and skills in a particular problem area. Some general continua of learning are described in the literature which may guide design of studies that focus on understanding developmental continua with respect to problems. Development of capabilities in a problem or knowledge domain is described by Messick (1984) and Anderson (1980) as a beginning stage where learners acquire a critical mass of information (declarative knowledge) on a subject followed by a second stage in which that knowledge is restructured into knowledge-dependent skill units that also incorporate general cognitive abilities. The second stage reflects integration of declarative and procedural knowledge and is followed by a more advanced stage in which more conscious restructuring and elaboration of stored knowledge occurs in relation to problem situations. Skill learning is described by Anderson (1980) as involving a cognitve stage in which a description of the procedure is learned, an associative stage in which a method for performing the skill is worked out, and an autonomous stage in which the skill becomes more rapid and automatic. Study of the second stage of learning has much potential to provide especially useful information for the design of educative processes since it is where knowledge proceduralization occurs and thereby moves knowledge from an inert to a usable form.

Protocol research methodology (Dillard, Bhaskar & Stephens, 1982; Larkin, 1979; Simon & Simon, 1979) would be especially useful in developmentally oriented studies because it allows comparison of a very comprehensive set of factors. Cognitive task analysis (Dillard, Bhaskar & Stephens, 1982; Lajoie, 1986) combined with the protocol approach (Dillard, Bhaskar & Stephens, 1982) would also be useful. Cognitive task analysis incorporates procedures from the behavioral task analysis methodology familiar to vocational educators. However, cognitive task analysis examines the relationships between cognitive processes and action and behavior and contrasts these two elements in the patterns of novices and experts (Greeno, 1980a; Magone & Yengo, 1986). Other potential methodologies for doing comparative studies of knowledge characterics or problem solving processes across a developmental continuum in a knowledge and problem domain include the tab item and in-basket techniques mentioned earlier, the techniques used in the Elstein, Shulman and Sprafka study (1978), concept maps

(Novak & Gowin, 1984), and techniques used in information processing research that reveal stored knowledge content and structure and intellectual processes (Anderson, 1980; Lachman, Lachman & Butterfield, 1979).

Better understanding of the stages of problem solver development is likely to help teachers be better able to diagnose where learners are having problems and to identify appropriate ways of helping learners overcome those problems (Brown & Burton, 1978; Marshall, 1980). Information from several of the above methodologies might be used for diagnostic purposes prior to and during instruction in order to identify areas where students have difficulties and to adjust instruction accordingly. An example of an instructional application of the protocol technique was carried out in the winter of 1986 in a fundamentals of power course at the University of Minnesota. The students, who had introductory knowledge of electricity theory and instrumentation, were asked to fix a high voltage electrical circuit consisting of a power source, fusible element, on/off switch, light socket, light bulb, and wire. The only information students were given was that the bulb did not light when the switch was turned on. Students worked in pairs and were asked to think out loud as they went about the task of solving the problem. A tape recorder recorded their verbal expressions. The tapes were then transcribed and thinking protocols were developed from the transcriptions. The protocols were examined for sequence, pattern, attentional focus, and concepts used. As a result, it was determined that some concepts used by students distracted their attention from the central and critical elements of the problem and, as a result, they investigated several "dead end" possibilities before pursuing possibilities that led to solving the problem. As a result, the instructional presentation of concepts that preceded this problem solving exercise was revised to focus more directly on the central concepts. This try out of the protocol method applied to instruction indicated that it yielded information useful to an instructor in diagnosing students' difficulties and needs and in adjusting and refining curriculum.

In addition to the type of problem, amount of knowledge available about the problem, or stage of learner development, choice of teaching method may also depend on instructional aims. For example, explicit teaching of problem identification and problem solving processes as rules or procedures to be followed would serve aims directed at proficiency in working with a specific kind of problem, whereas discovery and other experiential methods would be more likely to lead to the ability to generalize the acquired procedures to problems that do not closely fit the problem type being taught, thus serving adaptation and creativity aims.

The particular need for creativity and idea generation that ill-structured problems appear to require (Frederiksen, 1984) is one potential focus for instruction to develop learners' ability to work with such problems. Programs that have been developed to enhance creativity of learners (de Bono, 1967, 1970; Parnes, Noller, & Biondi, 1977) may prove useful in guiding the development of curricular designs and instructional processes that help students learn approaches for identifying and solving truly ill-structured problems (in terms of lack of existing knowledge). Another potential focus for teaching learners to work with these problems is focusing on the hypothesis generation and testing problem solving method which has been proposed as a likely primary method for solving ill-structured problems (Frederiksen, 1984). Learning experiences that encourage learners to identify a range of plausible answers are likely to be more valuable in this teaching than those that require learners to seek a single right answer.

What appear to be prerequisites for problem solving expertise can serve as focuses for instruction in identifying and solving well-structured problems. The prerequisites have been identified as a large hierarchically arranged knowledge base specific to an area of expertise that contains a pattern recognition system which reduces the information processing load and provides a system of retrieval aids for accessing desirable courses of action (Chase & Chi, 1980, pp. 11-12, 14). It has been suggested that condition-action units may comprise such a system (Simon, 1980). Given that practice in working with problems is identified as a primary way of achieving the prerequisites (Chase & Chi, 1980), the challenge for vocational education instruction is determining how curricular designs and instructional processes can provide students with the kinds of practice that will develop their problem solving abilities.

Automaticity in pattern recogniton and other aspects of problem identification and problem solving, while needed to achieve expertise in working with given types of problems, may also make students less alert to the emergence of a new problem for which familiar algorithms are not appropriate. Thus, two aspects of automaticity are relevant to instruction: 1) getting learners to automaticity levels with respect to familiar problems, and 2) enabling them to distinguish familiar from new problems that may have different requirements.

Teaching related to well-structured problems may present a considerably less complex instructional problem than teaching related to ill-structured problems. A danger that vocational educators and researchers should be alert to is the appeal of dealing with the easier, simpler problem and avoiding the more difficult job of understanding and helping students learn the complexities of working with ill-structured problems.

In a review of cognitive psychology theory in relation to its implications for instruction in problem solving, Frederiksen (1984) identified nine general approaches for teaching problem solving:

1. Teach cognitive processes underlying problem solving
2. Teach development of problem structures
3. Teach pattern recognition
4. Teach problem solving procedures
5. Teach the knowledge base relevant to identifying and solving various problems
6. Teach the development of knowledge structures
7. Teach aptitudes
8. Provide practice with feedback
9. Use models in instruction

Several of these strategies have already been discussed in connection with subquestions a and b of research question 3.

A number of courses in problem solving have been developed that may be useful in developing curricular design and instructional processes for developing problem solving expertise for problems and in contexts central in vocational education (Cyert,1980; Hayes, 1976; Larkin & Reif, 1976; Rubenstein, 1975, 1980). These and Elstein, Shulman and Sprafka's (1978) recommended approaches for teaching identification and solving of diagnosis problems are reviewed and summarized by Frederiksen (1984, pp. 372-373):

1. Help students get the total picture and avoid getting lost in detail
2. Help students learn to withhold judgment, refrain from commiting themselves too early
3. Teach students to create models to simplify the problem, using words, pictorial representations, symbols, or equations
4. Teach students to try changing the representation of the problem
5. Teach students to use verbalization, to state questions verbally, to vary the form of the question, to talk to someone else about the problem
6. Teach students to question the credibility of their own premises
7. Teach students to try working backward
8. Help students learn to proceed in a way that permits them to return to partial solutions
9. Teach students to use analogies and metaphors

The next four sections review what is suggested in the literature specifically regarding the teaching of problem representation, reduction and focusing, problem solving method selection, and solution generation and evaluation. Suggestions for assessing the effectiveness of alternative curricular designs and instructional approaches in developing these processes are also included. In addition to assessing effectiveness in developing understanding and use of the processes, impact on ability to transfer the processes to other contexts and to unfamiliar problems of the same type should be examined. The literature indicates that transfer of problem solving ability across different types of problems may not be a reasonable expectation. Little specific guidance for development of curricular designs and instructional processes that enhance transfer is reflected in the problem solving literature. An exception is Messick's (1984) recommendation of teaching two processes with parallel structures at the same time.

Facilitating Development of Problem Representation Processes

Educating the problem representation process is closely related to educating attention allocation and information-seeking processes. As previously stated, how a problem is identified influences what information about the problem will be sought and what solutions will be considered, and, conversely, information that is sought will also influence problem representation. In representing the problem, the problem solver identifies the structure of facts, concepts, and their interrelationships that make up the problem (Frederiksen, 1984) and that help the problem solver construct a network of relationships connecting the variables and features given in the problem with the variables and features of the desired solution (Greeno, 1973). Educating problem representation processes is likely to involve helping students learn: 1) approaches for identifying explicit and implicit factors in a problem situation, information that is given and that which would be worth developing; 2) patterns (schemas and scripts) for interpreting information; 3) ways of organizing problem factors in different kinds of problems; 4) ways of establishing and categorizing context(s) for a problem; and 5) ways of categorizing problems with respect to problem type.

Teaching pattern recognition is one recommended instructional strategy that is relevant to problem representation processes. Opportunities for students to work with well-structured problems which are clearly formulated and for which algorithms for solving them and criteria for testing correctness of solutions are known is likely to develop students' skills in recognizing the problem as a particular type and matching it with an algorithm that will solve it. Ways of teaching pattern recognition that have been identified include providing learners with extensive practice in recognizing the presence of situational cues and modeling of appropriate observational methods (Frederiksen, 1984). The use of films has been incorporated in such instructional approaches (Salomon, 1974). Instructional approaches already suggested for developing stored knowledge structures and knowledge acquisition processes would also be relevant to teaching pattern recognition. Providing more structure in problems for beginners and gradually reducing the amount of structure as students gain experience in representing problems has been suggested (Frederiksen, 1984; Willems, 1981).

Opportunities to work with ill-structured problems which are not clearly stated, do not provide a goal, provide little explicit information about states or conditions or the problem context, and for which there are multiple rather than single problems that might be identified and problem solving approaches possible (Simon, 1980) are likely to provide especially challenging experiences for learning problem representation processes. Providing students the opportunity to work with such problems will require them to generate all of these aspects of the problem and would give them the most in-depth and broadest scope of experience and practice with problem representation processes. Teaching students generalized problem identification and problem solving procedures may be especially helpful in preparing them to work with such problems (Simon, 1980).

Instructional designs that involve the student in generating questions (e.g., adaptation of the twenty questions research technique used by Elstein, Shulman and Sprafka, 1978, for instructional purposes may be possible) and interpreting information are more likely to be supportive of learning relevant to problem representation than are instructional designs which involve the student in search for one right answer such as looking up and repeating terms from textbooks, or performing a task in one, specific, prescribed way. Instructor demonstration and modeling of problem representation processes, with explicit identification of the thinking processes the instructor uses is another approach. Demonstration without explicit identification of processes followed by learner practice and instructor feedback is a way of teaching problem representation when the processes involved are not precisely known (Olson, 1976). Use of computers as intelligent tutors which model problem representation processes and provide students with feedback on their approaches to problem representation is another potential approach (Bonar & Logan, 1986; Lajoie, 1986).

Potential approaches for assessing change in problem representation-relevant concepts and skills as a result of instruction include pre- and post-instruction and experimental-control comparisons of printouts from computerized problems (White, 1984), questioning patterns revealed by the twenty questions technique, cognitive task analyses of student-generated protocols (Dillard, Bhaskar & Stevens, 1982; Lajoie, 1986), concept maps, and procedural sequences revealed by process tracing (Elstein, Shulman & Sprafka, 1978). Analyses of data generated through these means could focus on problem elements receiving attention and those ignored, the sequence in which problem elements are identified and investigated, the allocation of time to investigation of each element, the types, content and amount of information that is sought and obtained, the sequence in which it is sought, the sources from which it is sought and the methods by which it is sought, interpretation and evaluation of information obtained, the time spent seeking information, ways and formats in which information is recorded, the degree to which explict and implicit factors are identified, how the factors are organized, what is identified as desired in a problem and the conditions needed for the problem to be considered solved, what is identified as the conditions under which the problem must be solved, the context that is established for a problem and its categorization, how a problem is categorized, and the degree of flexibility and rigidity that is reflected in representations developed for different problems.

Facilitating Development of Problem Reduction and Focusing Processes

Problem reduction and focusing, as stated in connection with research question 2, involves paying attention to some elements in or relevant to the problem situation and eliminating other elements from attentional focus in order to carve out of the total situation a problem space that will be worked with in detail. Educating problem reduction and focusing processes will involve helping learners: 1) develop approaches for selecting problem elements that have a high probability of leading to a solution, and for identifying or developing needed information; 2) develop schemas and scripts for relevant cue-action patterns and for identifying cause-effect relationships, goal(s) to be reached, resources available or that could be developed, and potential means, tools or operators that could be used in solving the problem.

Pattern recognition is relevant to problem focusing and reduction. Expert problem solvers appear to have stored in memory a number of strategies which can be retrieved when appropriate cues are present in a problem solving situation. Increasing the pattern recognition abilities of learners with respect to problem reduction and focusing is likely to involve helping learners to explicitly understand alternative goals, resources and operators, for example, and helping them link these with situational cues in memory (Bhaskar & Simon, 1977). This strategy is analogous to teaching condition-action units described in connection with knowledge arrangement and integration. Pattern recognition might also be learned through teaching students a feature detection strategy in which they learn to systematically scan the task situation for cues (Glaser,1976b). Instructional approaches already suggested for developing stored knowledge structures and knowledge acquisition processes would be relevant to teaching pattern recognition.

Schema abstraction underlies pattern or schema development and storage. Helping learners to develop schemas involves beginning with a domain that the learner is already familiar with and presenting a new target domain that differs only in small ways according to number of dimensions, attributes and operations (Messick, 1984). Such learning is used considerably in real life situations

(Rogoff & Lave, 1984; Rumelhart & Norman, 1981; Vgotsky, 1978). Scaffolding and propleptic teaching would appear to be useful approaches for accomplishing this. As explained earlier, scaffolding is a term applied to the technique of linking the learner where he or she is to new learning. Rogoff and Gardner (1984) describe the process as, "When faced with a new problem, individuals weave what they know about solving other problems and information about the new problem into a more coherent approach which transforms the novel problem into a more familiar problem. The thinker makes use of whatever is familiar in the context of the new problem to apply information and skills available from familiar problems in bridging a solution to the novel problem." (p. 96). The role of the teacher, coach, or expert may be to provide guidance in creating links between the context of a novel problem and more familiar problem contexts, allowing the application of available skills and information. Headfitting is a term that has been applied to making new information compatible with learners' current knowledge and skills (Brown, 1979, p.251). Propleptic teaching, as indicated earlier, involves the teacher and learner together in joint management of and working through a problem solving process.

Egan and Greeno (1973) found that discovery learning was more effective than teaching rules in learners' ability to reorganize a problem space. Teaching rules tended to result in additions to an existing structure. This finding supports the speculation that experientially-oriented teaching approaches are more effective than didactic approaches in teaching the complex cognitive processes involved in problem reduction and focusing.

Instructional designs similar to those already mentioned in connection with problem representation would be appropriate for teaching problem reduction and focusing, including twenty questions-type approaches, instructor demonstration and modeling of problem reduction and focusing processes and explicitly identifying the thinking processes involved, demonstration without explicit identification of processes followed by learner practice and instructor feedback, and using computers as intelligent tutors.

Additional suggestions for teaching problem focusing and reduction processes include teaching ways of redefining the problem such as reversing problem elements, formulating verbal restatements of the problem (Stein, 1978), and using metaphors and analogies (Simon & Hayes, 1976; Stein,1978), teaching students to verbalize goals (Resnik, 1976) and to pay attention to semantic cues (Simon & Hayes, 1976), teaching strategies for organizing, controlling, and monitoring analysis of problem features (Pellegrino & Glaser, 1980), giving students practice in asking questions and in thoroughly searching and considering given information in a problem presentation, as well as in testing for ambiguities in the information (Simon & Hayes, 1976), and teaching students sources of information to explore including the task instructions, students' previous experience with the same or very similar task, their previous experience with analogous tasks or with components of the task, procedures for combining their stored knowledge with information provided in the task instructions, and accumulated information they develop as they work with the problem (Simon & Newell, 1971).

Approaches for assessing change in problem reduction and focusing processes as a result of instruction can be developed from research approaches recommended in connection with research question 2. These include protocols (Dillard, Bhaskar & Stephens, 1982; Easley, 1979; Lockhead, 1979; Mayer, 1975), cognitive task analysis (Dillard, Bhaskar, & Stephens, 1982; Lajoie, 1986) tracking computer printouts of students' inputs in interactive computer games or simulations or problems (White, 1984), and the process tracing method (Elstein, Shulman & Sprafka, 1978). Experimental-control comparisons of pre- and post-instructional data generated using these approaches can be done to determine the impact of instruction on problem reduction and focusing processes. Specific analyses can be carried out to detect change in problem elements receiving attention and problem elements ignored, the sequence of attentional focus, allocation of time to various problem elements, the types, content and amount of information sought and obtained, the sequence in which information is sought and obtained, the sources from which and methods by which information is sought and obtained, interpretations and evaluations applied to information obtained, the time allocated to information-seeking, ways and formats in which information is recorded, problem space elements (key elements in present and desired states of affairs, cause-effect relationships, goal(s), resources, and means, tools or operators) identified, and the degree of flexibility and rigidity that is reflected in problem spaces developed for different problems. A technique for detecting increase in pattern storage relative to a type of problem involves presenting a problem situation to learners, removing it, and then asking the learners to write as much about the situation as they can remember. As pattern storage increases, learners will be able to recall increasing amounts of information about the situation (Norman, Jacoby, Geightner, & Campbell, 1979; Wortman, 1972). Frederiksen (1984) recommends measures of speed for detecting development of pattern recognition abilities and automatic processing skills.

Facilitating Development of Problem Solving Method Selection Processes

Problem solving method selection has to do with the selection of an approach or approaches for generating potential problem solutions. Educating the problem solving methods selection process will involve helping learners: 1) identify factors upon which problem solving method selection might be based and cues that represent them, 2) identify information needs in selecting a method and ways to address them, 3) learn a range of problem solving methods, 4) learn procedures and schemas for selecting alternative potential problem solving methods, and for evaluating the usefulness of alternative methods for different kinds of problems and conditions.

Pattern recognition is also relevant to problem solving method selection. Increasing the pattern recognition abilities of learners with respect to method selection processes is likely to involve helping learners to explicitly understand alternative methods and helping them link situational cues and methods (i.e., form condition-action units) in memory (Bhaskar & Simon (1977). Instructional approaches already suggested for developing stored knowledge structures and knowledge acquisition processes would be relevant to teaching pattern recognition. Providing guided practice as in the propleptic teaching method and the scaffolding technique would be appropriate teaching processes. Willems (1981) outlines how this might be done in teaching problem solving.

Resnik (1976) suggests teaching students to verbalize strategies for solving a problem before making actual moves toward solution. Polya's classic book (1946) provides a number of problem solving approaches which could be taught. Other references that provide some detail on different problem solving methods are Greeno (1980b), Larkin (1980), Sacerdoti (1977), Simon (1980), and Wickelgren (1974). Methods suggested for teaching problem representation and problem reduction and focusing would be relevant to teaching the problem redefinition method of problem solving.

The likelihood of different kinds of problems requiring different problem solving methods (Greeno, 1978a) has already been mentioned. Helping students learn which kinds of methods are likely to be useful in solving which kinds of problems and how to use the methods is likely to be a useful approach for teaching problem solving method selection. For example, a study by Sweller and Levine (1982) has demonstrated that means-end analysis is more likely to be used when the goal is clearly specified and cannot be used when the goal is not specified. Further, when means-end analysis is used, students tend not to learn much about the structure of the problem. Research involving trouble shooting-diagnosis problems has indicated the likelihood of a hypothesis generation and testing method of problem solving being particularly functional for such problems (Elstein, Shulman & Sprafka, 1978). Moshman (1979) identified three understandings required by this method: Understanding conditional relationships, understanding that hypothesis testing requires information that refutes the hypothesis, and understanding that hypotheses are not conclusively proven by data that supports them. Other researchers have suggested the need to alert students to the predictive value of information that is present as well as that which is absent in hypothesis generation and testing (Christensen-Szalanski & Bushyhead, 1981).

Using computers as intelligent tutors to model problem solving methods, guide student selection and application of methods, and to provide feedback to students on their method selection procedures has been tried in technical education (Bonar & Logan, 1986; Lajoie, 1986). Such approaches are analogous to coaching situations (Burton, Brown, & Fischer, 1984) which provide individualized guidance and feedback by an expert to the learner. Such "coaching systems" provide more structure and explicit guidance than do "pure" discovery approaches, but are not as explicit as rule-teaching methods. The coaching probably functions to make the learner more efficient in their discoveries by focusing their attention and providing needed information.

Approaches for assessing development in problem method selection processes as a result of instruction might be adapted from research methodologies recommended in connection with research question 2. These include protocols (Dillard, Bhaskar & Stephens, 1982; Easley, 1979; Lockhead, 1979; Mayer, 1975), cognitive task analysis (Dillard, Bhaskar, & Stephens, 1982; Lajoie, 1986), tracking computer printouts of students' inputs in interactive computer games or simulations or problems (White, 1984) and the process tracing method (Elstein, Shulman & Sprafka, 1978). Data generated by learners during problem solving method selection can be subjected to pre- and post-instruction analyses and experimental-control comparisons to determine impact of instruction on problem solving method selection processes. Specific analyses can be carried out to detect change in amounts of time allocated to problem method selection, problem elements receiving attention and those ignored and the sequence in which problem elements receive attention, the allocation of time to investigation of each element, what information is sought from what sources, the sequence in which it is sought and the methods by which it is sought, ways information is recorded, formated, and manipulated, interpretations of the meaning and value of the information obtained, the time spent seeking information, factors considered in identifying problem solving method(s), the sequences in which factors are considered and methods are identified, the methods(s) selected and sequence of selection, the degree of flexibility or rigidity reflected in choice of method(s) over different problems, and the effectiveness of the method(s) in generating effective and acceptable solutions. Techniques for asessing the development of stored patterns, pattern recognition skills, and automatic processing mentioned in connection with assessment of problem reduction and focusing in the previous section would also be applicable for assessing these developments in connection with problem method selection.

Facilitating Development of Solution Generation and Testing Processes

The solution generation and evaluation process involves the generation of potential problem solutions and their testing to see if they are effective in solving the problem and acceptable for its context and constraints. Educating solution generation and evaluation processes is likely to involve helping the learner: 1) apply a range of problem solving methods appropriately, thoroughly, and accurately in the generation of solutions, 2) identify solution evaluation criteria and recognize the function of the problem identification processes in their generation, 3) develop schemas and scripts for accurately and thoroughly applying solution evaluation criteria to generated solutions and for interpreting solution test information.

Pattern recognition skills of concern in connection with problem solution generation and testing would be those relevant to making conclusions about solution tests. For example, learning identified as relevant to the testing of potential solution hypotheses in the hypothesis generating and testing problem solving method include understanding the need for information that refutes the hypothesis and understanding that hypotheses are not conclusively proven by data that supports them (Moshman, 1979). Teaching students to be alert to potential biases in interpreting hypothesis test information has also been suggested (Doherty, Mynatt, Tweney, & Schiavo, 1979; Mynatt, Doherty, & Tweney, 1977).

Instructional designs that involve the student in interpreting information are likely to support solution evaluation. Exercises that give students practice in applying criteria and making conclusions about the results would be a way of strengthening the cognitive processes underlying solution evaluation. Instructor demonstration and modeling of solution generation and of the evaluation process in which criteria are applied to the solution with explicit identification of the thinking processes the instructor uses is another possible approach as is propleptic teaching. Use of computers as intelligent tutors which model solution generation and evaluation processes and provide students with feedback on their own solutions is also an approach that is being developed (Bonar & Logan, 1986; Lajoie, 1986).

Approaches for assessing development of problem solution generation and evaluation processes as a result of instruction can be adapted from research methodologies recommended in connection with research question 2. These include protocols (Dillard, Bhaskar & Stephens, 1982; Easley, 1979; Lockhead, 1979; Mayer, 1975), cognitive task analysis (Dillard, Bhaskar, & Stephens, 1982; Lajoie, 1986), tracking computer printouts of students' work with interactive computer games or simulations or problems (White, 1984) and the process tracing method (Elstein, Shulman & Sprafka, 1978). Data generated by learners during solution generation and evaluation can be subjected to pre- and post-instruction analyses and experimental-control comparisons to determine impact of instruction on problem solution generation and evaluation. Specific analyses can be carried out to detect change in amounts of time allocated to solution generation and evaluation, what solutions are generated and how they are evaluated, the sequence in which solutions are generated and what factors are considered in their generation and evaluation, sequence of attentional focus preceding and following solution generation and evaluation, the allocation of time to elements preceding and following solution generation and evaluation, what information is sought and the sequence in which it is sought preceding and following solution generation and evaluation, what information is recorded and the way it is recorded, interpretations and evaluations of solution test results, the number of solutions generated, the number and proportion of generated solutions evaluated as effective and acceptable, and as effective and unacceptable, range of types of solutions generated, the degree of creativity expressed in generated solutions, the accuracy and of solution evaluation, and the degree of flexibility or rigidity reflected in solutions generated over different problems.

Strengthening Dispositions That Enhance Ability to Work With Problems

Learning style should be incorporated as a control variable in assessing the impact of various curricular designs and instructional processes on the learning of problem identification and problem solving processes. In addition, alternative approaches to teaching problem identification and problem solving processes might be developed for different learning styles.

Protocols and stimulated recall techniques used to study the learner's bases for attention allocation and information-seeking in relation to problem identification and problem solving can be analyzed for interests, motivations, priorities and attentional biases across time and problems. Data from these techniques will also reveal the degree of self-awareness of the learner regarding their own problem identification and problem solving processes. Sharing information about their own interest, motivational, priority and attentional bias patterns with learners should help to develop their self awareness. Another approach that may be even more effective in building self-awareness is having learners do their own analyses of protocols and stimulated recall data to uncover their own patterns and those of each other. Use of the tab item and in-basket techniques as instructional tools and having students analyze their own paths through problems is another approach to developing self-awareness of problem identification and problem solving processes. Helping students develop self-awareness of their own problem solving processes is addressed in the problem solving course developed by Hayes (1976).

Questioning patterns used by instructors could be examined in relation to increasing enduring interest, motivations, priorities and values in learners that are functional for problem identification and problem solving. The nature of questions and questioning used in instruction should be studied with respect to the extent to which students versus instructors formulate questions that guide learning, the nature of the questions with respect to open-endedness versus closed endedness, generativeness versus convergence, condition-action linkage orientedness, memory versus thinking dependent, and elaboration- and creative response-inducing versus conforming response-inducing. Further, responses of instructors to student responses to questions and to student generated questions should be studied with respect to encouraging elaboration or encouraging closure, encouraging students to take risks versus encouraging students to conform, etc. The educational climate set by the instructor and that which pervades the educational context (see the discussion in the overview section of this chapter) might also be examined for impact on enduring dispostions of learners.

Summary

The research agenda that has been presented is ambitious. It will take many individuals and several years to address it in its entirety. The research endeavors it contains are varied, providing opportunities for researchers and educators with varying interests to pursue them. These individuals will need a pioneering spirit and to be able to tolerate ambiguity, for all the chips are not in place at this time. Pursuit of the challenge seems most worthwhile, however, for it offers opportunities not previously matched for understanding learning and ways of enhancing it. Such is the essence of education at its most basic foundation.

The five educational problems discussed in Chapter I have been elaborated over the succeeding pages. They are truly ill-structured problems, for the knowledge required to solve them has not been available. Ways of applying knowledge now available to solve the five problems, or to redefine them so that progress in solving them can be made, have been presented. What is needed now is for researchers, policy makers and educators to focus their attention, efforts, and influence on the many studies that are needed and to cooperate in ways that will make the inquiries possible.

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INQUIRY AGENDA

OBJECTIVES AND VARIABLES

I. Identify and organize problems central in vocational education and their requirements

- A. Identify significant, recurring types of problems that arise within contexts central in vocational education
- B. Identify key features of problem types and the different forms these features take in specific problems.
- C. Identify types of knowledge, thinking processes, and dispositions, (e.g., interests, motivations, values, priorities) needed to work with each problem type.

II. Describe and document the knowledge, cognitive abilities and dispositions that guide, organize and form effective action in working with problems and in contexts central in vocational education.

- A. Characteristics of stored knowledge
    1. Content
    2. Amount
    3. Arrangement
    4. Complexity
    5. Integration

- B. Knowledge acquisition processes
    1. Attentional focus
        - a. Object(s)
        - b. Time allocated to object(s)
        - c. Sequence
        - d. Accuracy and extent of cue perception
        - e. Relevance, significance of object(s)
        - f. Bases for attention allocation
        - g. Degree of automaticity

    2. Information seeking
        - a. Type, content and amount of information sought and obtained
        - b. Sequence in which information is sought and obtained
        - c. Sources from which information is sought and obtained
        - d. Methods by which information is sought and obtained
        - e. Recording of information obtained
        - f. Relevance/significance of information sought and obtained and accuracy of information obtained

    - g. Time allocated to information searches and sources
    - h. Interpretation and evaluation of information obtained
    - i. Bases for types and amount of information sought, source and methods selection, and sequence of information seeking
    - j. Degree of automaticity

C. Processes used in identifying and solving problems and their results

- 1. Problem representation
    - a. Allocation of time to problem representation
    - b. Problem elements receiving attention, problem elements ignored
    - c. Sequence of attentional focus
    - d. Allocation of time to elements
    - e. Types, content and amount of information sought and obtained
    - f. Sequence of information sought and obtained
    - g. Sources from which information is sought and obtained
    - h. Methods by which information is sought and obtained
    - i. Interpretation and evaluation of information obtained
    - j. Allocation of time to information seeking
    - k. Bases for attention allocation and information seeking
    - l. Automaticity of attentional focus and information seeking
    - m. Recording and manipulation of information
    - n. Identification of factors in the problem situation and the sequence in which they are identified
        - 1). Explicit factors
        - 2). Implicit factors
    - o. Organization of factors
    - p. Identification of what is desired in the problem, conditions that must exist in order for problem to be considered solved, and the conditions under which problem must be solved
    - q. Sequence in which what is desired in the problem, conditions that must exist in order for problem to be considered solved, and the conditions under which problem must be solved are identified, the factors that are considered in their identification, and the relationship of problem elements attended to and information sought and obtained to these aspects of the problem representation
    - r. Context established for the problem and its categorization and relationship of problem elements attended to and information sought and obtained to the context identified and its chosen categorization
    - s. Categorization of the problem and relationship of problem elements attended to and information sought and obtained to the problem categorization

2. Problem reduction and focusing processes
    a. Allocation of time to problem reduction and focusing
    b. Problem elements receiving attention, problem elements ignored
    c. Sequence of attentional focus
    d. Allocation of time to elements
    e. Types, content and amount of information sought and obtained
    f. Sequence of information sought and obtained
    g. Sources from which information is sought and obtained
    h. Methods by which information is sought and obtained
    i. Interpretation and evaluation of information obtained
    j. Allocation of time to information seeking
    k. Bases for attention allocation and information seeking
    l. Automaticity of attentional focus and information seeking
    m. Recording and manipulation of information
    n. Identification of problem space elements: key elements in present and desired states of affairs, cause-effect relationships present in problem situation, goal to be reached, resources available, and means, tools or operators with which problem can or must be solved
    o. Sequence in which problem space elements are identified, the factors that are considered in their identification, and relationship of problem elements attended to and information sought and obtained to the problem space elements identified
    p. Relationship between identified context, states, goals, resources and means

3. Problem-solving method selection
    a. Allocation of time to problem-solving method selection
    b. Problem elements receiving attention, problem elements ignored
    c. Sequence of attentional focus
    d. Allocation of time to elements
    e. Types, content and amount of information sought and obtained
    F. Sequence of information sought and obtained
    g. Sources from which information is sought and obtained
    h. Methods by which information is sought and obtained
    g. Interpretation and evaluation of information obtained
    i. Allocation of time to information seeking
    j. Bases for attention allocation and information seeking
    k. Automaticity of attentional focus and information seeking
    l. Recording and manipulation of information
    m. Methods considered and methods ignored, sequence in which methods are considered, and relationship of problem elements attended to and information sought and obtained to methods considered
    n. Method(s) selected, sequence of selection, and factors considered in method selection
    o. Effectiveness of methods selected in generating effective and acceptable solutions

4. Solution generation and evaluation processes and results
    a. Allocation of time to solution generation and evaluation
    b. Solutions generated and evaluated, sequence in which they are generated and factors considered in their generation and evaluation
    c. Sequence of attentional focus preceding and following solution generation and evaluation
    d. Allocation of time to elements preceding and following solution generation and evaluation
    e. Types, content, amount, and sequence of information sought preceding and following solution generation and evaluation
    f. Bases for attention allocation and information seeking
    g. Automaticity of attentional focus and information seeking
    h. Recording and manipulation of information
    i. Interpretations and evaluations applied to solution test results
    j. Number of solutions generated
    k. Number and proportion of generated solutions evaluated as effective but unacceptable and as effective and acceptable
    l. Degree to which solutions generated represent different types of solutions or variations of the same type
    m. Degree of creativity expressed in generated solutions
    n. Accuracy of solution effectiveness evaluation

D. Dispositions
  1. Learning/information processing/cognitive style
  2. Flexibility/rigidity in problem representation, focusing, method selection and solution generation across varied problems
  3. Enduring interests, motivations, priorities, values and attentional biases
  4. Momentary intentions, interests and motivations
  5. Self/meta-cognitive awareness

III. Identify, develop and assess curricular designs and instructional processes that facilitate development of stored knowledge, knowledge acquisition processes, problem identification and solving processes and dispositions that enhance ability to work with problems and in contexts central in vocational education

A. Improve stored knowledge
  1. Increase knowledge retention
  2. Facilitate development of functional arrangements of stored knowledge
  3. Increase complexity of stored knowledge
  4. Increase integration of stored knowledge
  5. Address differences in learning styles
  6. Increase learners' self-awareness of the characteristics of their stored knowledge
  7. Increase transfer of knowledge

B. Improve knowledge acquisition processes
   1. Enable learners to develop, direct and control their own attentional-focus patterns
   2. Enable learners to develop, direct and control their own information-seeking patterns
   3. Address differences in learning styles
   4. Increase learners' self-awareness of their attentional focus and information-seeking patterns, learning style, and enduring interests and motivations, and the impact of these on knowledge acquisition processes
   5. Enable learners to develop enduring interests, motivations, priorites, and values that are functional in attention-focusing and information-seeking in relation to goals

C. Improve problem identification and problem solving processes
   1. Facilitate development of problem identification and problem solving processes in learners at varying levels of development with respect to problem and knowledge domains
   2. Facilitate development of problem identification and problem solving processes for problems with varying amounts of structure
   3. Develop problem identification and problem solving prerequisites
   4. Develop problem representation processes
   5. Develop problem reduction and focusing processes
   6. Develop problem solving method selection processes
   7. Develop problem solution generation and testing processes

D. Strengthen dispositions that enhance ability to work with problems
   1. Increase learners' self-awareness of their own learning style
   2. Increase flexibility in learners' application of problem identification and problem solving processes
   3. Increase self-awareness in learners of their own problem identification and problems solving processes
   4. Enable learners to develop enduring interests, motivations, priorites, and values that are functional in problem identification and problem solving